FEBRUARY 27, 1961

nissiles and rockets

HE MISSILE/SPACE WEEKLY

V.8 #9

4th Annual Electronics Issue

Why the $1 Billion Guidance and Control Market Will Grow Bigger

First G&C Details:

- *Minuteman*
- *Titan II*
- *Dyna-Soar*
- *Saturn*

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Antenna Guides Titan Shot

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Double-Wall by Bell — symbolized

BELL COOLS THE HEAT OF HOMECOMING

Atmospheric friction which will slow tomorrow's returning space vehicles to safe landing speeds can make cinders of both space ship and occupants.

Bell Aerosystems has worked since the days of the X-1 supersonic research plane to beat this heat. We call our system Double-Wall. We've tested it — and we know it works.

Double-Wall is made up of a heat-sustaining outer wall, a sublayer of thermal insulation and a cooled inner wall. The fundamental principle behind this arrangement is the separation of the heat-sustaining and load-carrying functions of the airframe.

The outer wall is made up of small heat-resistant panels designed to withstand severe heating. It carries no structural loads, but serves as an effective heat shield by radiating most of the re-entry heat back to the atmosphere.

The layer of protective insulation is used beneath these panels to resist the flow of heat to the inner wall. The small amount of heat that does penetrate this insulation is absorbed and dissipated by an effective cooling system. Therefore, though outer wall temperatures may soar above 2000° F, the inner wall temperature will not rise above 200° F.

Significantly, the load-carrying structure is kept cool and strong, independent of external heating, and conventional aluminum construction can be utilized. As an added bonus, the Bell Double-Wall's unique arrangement of thermal barriers automatically provides a moderate environment for both crew and equipment.

Double-Wall is only one of the many contributions Bell Aerosystems Company is making to the scientific progress and defensive strength of the free world. We invite qualified engineers and scientists to inquire about sharing our challenging and rewarding future.

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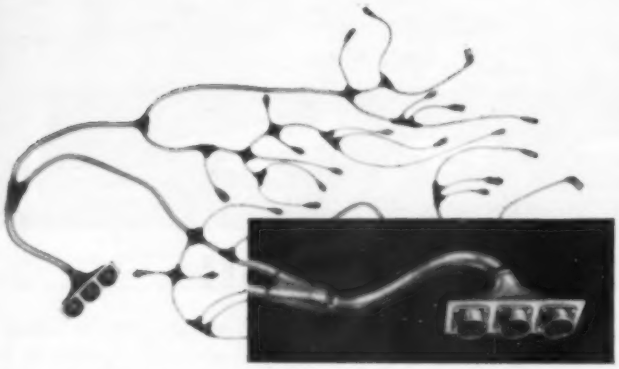
General Electric Silicone Rubber helps get Titan ICBM combat-ready

Missile and ground-support applications are "naturals" for the unique qualities of silicone rubber—heat resistance above 600°F, low-temperature flexibility to −150°F, good thermal conductivity, unexcelled ozone resistance and virtually unlimited life under normal conditions. Because it retains its excellent electrical properties over a wide temperature range, G-E silicone rubber is also used for missile wire and cable insulation. Even when continuously exposed to direct flame, it forms a non-conducting ash which gives off no toxic fumes.



Missile wiring harness — General Electric silicone rubber was chosen by Aerojet-General Corp. for the Titan's propulsion system wiring harness. Breakouts and junctions are molded from G-E RTV (room temperature vulcanizing) silicone rubber; wiring is silicone insulated; jacketing is high-strength G-E silicone rubber. Inset shows silicone rubber inserts in connectors. RTV is used in other missiles as a shock-absorbing encapsulant and potting material for electronic assemblies.

200 tons of steel and concrete — Titan missile silo doors by American Machine & Foundry Co. use seals of G-E silicone rubber. AMF also used G-E silicone rubber door seals on the Titan's ground support entry portals and radar silos. Silicone rubber can withstand the heat of rocket blast-off or possible atomic attack while remaining stable in storage for long periods.

GENERAL ELECTRIC

Write for more information on G-E silicone rubber, briefly describing your application. Section 0234, Silicone Products Department, Waterford, New York.

Circle No. 9 on Subscriber Service Card.

Sperry "flies" them all

The highest levels of performance and reliability in pilotless flight are currently being attained at Sperry Phoenix. Working with the Department of Defense and in cooperation with other leading American defense contractors, Sperry has played a major role in "droning" virtually every type of airborne vehicle.

Soon the Lockheed F-104 – with a special Sperry drone stabilization and control system – will fly precision, unmanned missions for the U.S. Air Force at double-sonic speed and altitudes of 60,000 feet and above. It is the fastest of pilotless aircraft, just as the Sperry-equipped QB-47 is the largest. To meet the Army's difficult battlefield surveillance mission, Aerojet-General's SD-2 reconnaissance drone also employs Sperry stabilization and control.

No organization has had more experience in drone control than Sperry. Beginning with the first aerial torpedo in 1915, this experience covers a wide spectrum, including QB-17, QF-80, SD-2, QB-47 and QF-104. Sperry Phoenix now is delivering to USAF a revolutionary Microwave Command Guidance System permitting precision remote control of many types of pilotless craft over hundreds of miles.

Sperry's pilotless flight capability encompasses both components and complete systems . . . points to a host of new applications, including the newest and most challenging—spacecraft and rocket-booster recovery.

SPERRY

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THE MISSILE / SPACE WEEKLY

missiles and rockets

Volume 8, No. 9 February 27, 1961

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THE COVER

Antenna in foreground beams command signals to radio-guided Titan I following launching at Cape Canaveral. (Photo courtesy Bell Telephone Laboratories. See story on p. 28.)

FEBRUARY 27 HEADLINES

FOURTH ANNUAL ELECTRONICS ISSUE

GUIDANCE AND CONTROL—A SPECIAL SURVEY 15

Space Work Will Lift Market to $1.5 Billion 16
Gyroscopes of All Types Face Design Changes .. 21
Computers Will Determine Space Achievements 24
'MiniWeld' Provides Erector-Set Computers 26
Inertial vs. Radio Command: Which Is Best? 28
Weight Cut, Reliability Added in Atlas 30
Titan II System to be Flight-tested Soon 33
Minuteman Guidance Called 'Most Reliable' .. 37
NASA Ready to Decide on System for Saturn .. 40
X-15 Flight Data System Forerunner for Space .. 42
Dyna-Soar Will Rely on Proven Components .. 45

Fight Looms over Missile Satellite Defense Plans .. 77
Mercury Atlas Firing Buoys Man-in-Space Hopes .. 80
Transit III-B Firing Is Only Qualified Success 81
Discoverer Program Scores Five Important Firsts 82
Explorer IX—First Satellite with All-solid Boost 83
Aerospace Projects Call for Tripling Technicians ... 85

DEPARTMENTS

Letters 8
The Countdown 13
Industry 70
Names in the News .. 74
When and Where 87
Reviews 87
Products & Processes .. 88
Contracts 90
Editorial 92

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memo from the publisher

HERRICK

WE ARE TODAY a nation of "space-conscious" people. Hardly a day goes by that a satellite launching, a new development in space medicine, a new design for a manned spacecraft doesn't get top news billing.

Since M/R's very first issue, in October, 1956, we have placed high emphasis on editorial coverage of space systems and space engineering. From now on we'll increase our emphasis on space, taking a major step in that direction this week with the appointment of John W. Herrick as Space Editor.

Until now, John has been a member of the technical staff in the Office of Scientific and Engineering Relations at Space Technology Laboratories. He brings to his new job a wealth of knowledge in the space field.

He has had 23 years of experience as a design engineer concerned with rocket engines, missiles, space programs and test facilities. He's the author of "Rocket Encyclopedia Illustrated." His most recent activities at STL included the editing and publishing of two new monthly publications: *Live Deadlines* and the *STL Space Log*. He organized and directed the STL Space Information Center and Visual Aid Office.

A fellow of the Society of Technical Writers, Herrick as also a member of the American Astronautical Society, the American Rocket Society, the Pacific Rocket Society, the Air Force Association and the American Ordnance Association, and a fellow member of the British Interplanetary Society.

With MISSILES AND ROCKETS, John Herrick's main assignment will be to step up our coverage of activities in the space field. His addition to our Los Angeles bureau means that no other publication in our field—monthly or weekly—now maintains a larger fulltime West Coast staff. It also presents conclusive evidence of the high regard in which we hold the West Coast as one of the most vital areas of adequate missile/space industry coverage.

* * *

LAST WEEK on this page we mentioned that M/R's Special Report on *Nike-Zeus* had been inserted in the Congressional Record on Feb. 2 by Senator Strom Thurmond (D-S.C.). Less than two weeks later, on Feb. 13, M/R's exclusive report on the Soviet military budget (M/R, Jan. 23, p. 14) was placed in the Congressional Record by Rep. Overton Brooks (D-La.), chairman of the House Space Committee. These are far from being M/R's first two entries into the archives of Congressional proceedings, but, if memory serves us correctly, this is the first time it's happened twice in one month.

* * *

Speaking of the *Nike-Zeus* report, we now have available a limited number of attractive reprints of that special report. You can order one by sending twenty-five cents to Reprints, MISSILES AND ROCKETS, 1001 Vermont Ave., Washington, D.C.

* * *

Those of you who frequently use MISSILES AND ROCKETS for research will be pleased to know that the Readers' Guide to Periodical Literature has selected M/R for indexing. Readers' Guide is received by approximately 11,000 libraries in the U.S. and abroad.

* * *

One of our important editorial tasks is to keep you up to date on the markets of the missile/space industry. You will find that the article leading off this annual electronics issue is the most thorough rundown on the billion-dollar guidance and control market compiled to date. If you are working in the field, thinking of getting in to it, or just plain interested because it's a vital part of our industry, you'll find it well worth reading. Electronics Editor Charles D. LaFond surveyed more than 100 firms in the field for the information. The article begins on p. 16.

Edwin A. Mickelfield

SPACE ENGINEERS

NAA's Space and Information Systems Division is taking an aggressive role in the nation's developing space program. Research is the key to the successful development and synthesis of the manned and unmanned space vehicles of the future. If you are a Physicist or Electronics engineer with an advanced degree—possess an innate curiosity about, and an intense interest in, any of the yet unexplored workings of the universe—let us tell you more about some of the key positions we have available in some of the following areas:

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M. R. Cunningham, Manager
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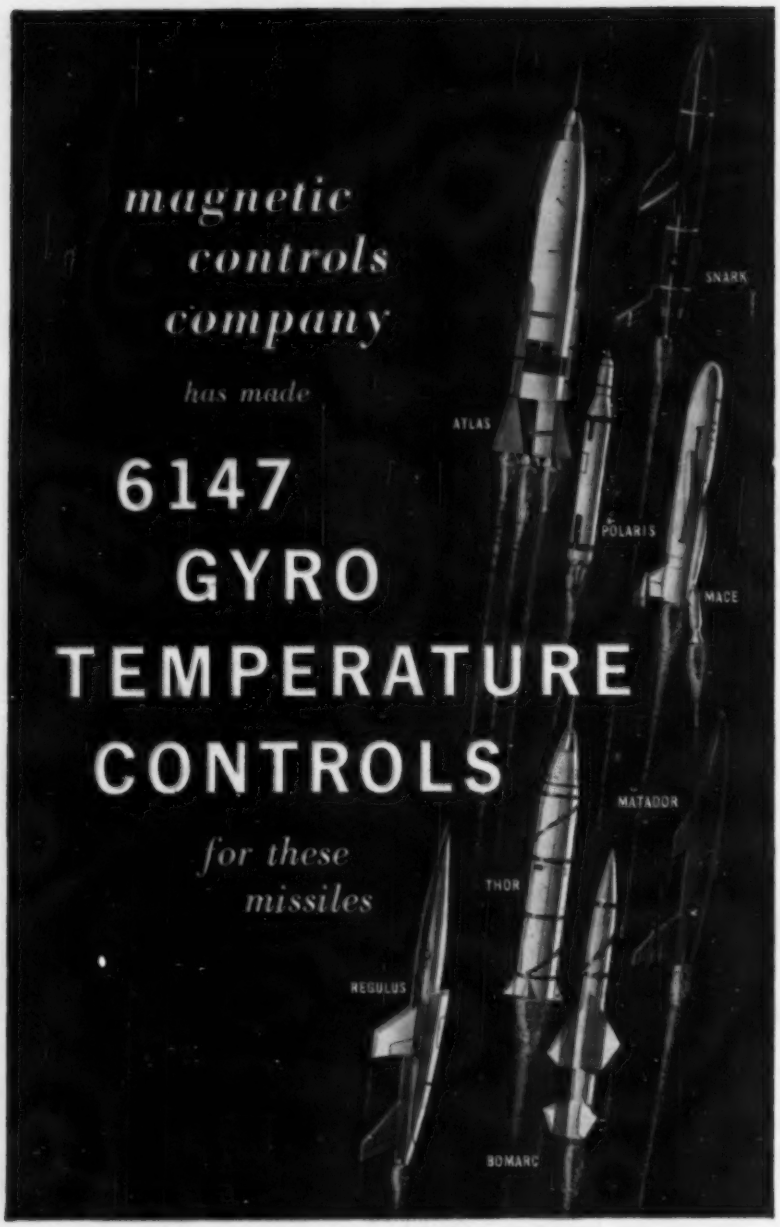

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letters

Fishing with Rockets

To the Editor:

We are interested in obtaining the names of manufacturers of small solid-fuel rockets. These should be in the size range of those used to loft fire extinguishing bombs for the U.S. Forest Service.

We are contemplating the use of such rockets to spread experimental fish nets.

Paul Kruse, Jr.
Fishery Methods & Equipment Specialist
Pascagoula Fishery Station
Bureau of Commercial Fisheries
Fish and Wildlife Service
United States Department of the Interior
P. O. Box 630
Pascagoula, Miss.

Manufacturers please note.—Ed.

Photo Breakthrough?

To the Editor:

Your article on the *Samos II* (M/R Feb. 6, p. 15), quotes industry sources as saying that the photographic equipment in the 3½ x 4 ft. payload can take detailed photos at 300 miles, equivalent to what the human eye would see at 100 ft.

You question what the Russian reaction will be to the *Samos*. If the Russians read MISSILES AND ROCKETS, I am sure the reaction will be complete and utter disbelief.

The human eye can resolve about one minute of arc. If a camera were at 300 miles, which is 16,440 times farther away than 100 feet, it would have no resolve 1/16,440 minutes or less than .004 seconds of arc. As any "industry source" can tell you, this is very high resolution.

A rule of thumb for diffraction limited resolving power, using visible light, is that the diameter of the optics in inches equals 4.56 divided by the resolving power in seconds. 4.56/.004 equals 1000 inches in this case. The optics in *Samos II* must be the ultimate in microminiaturization.

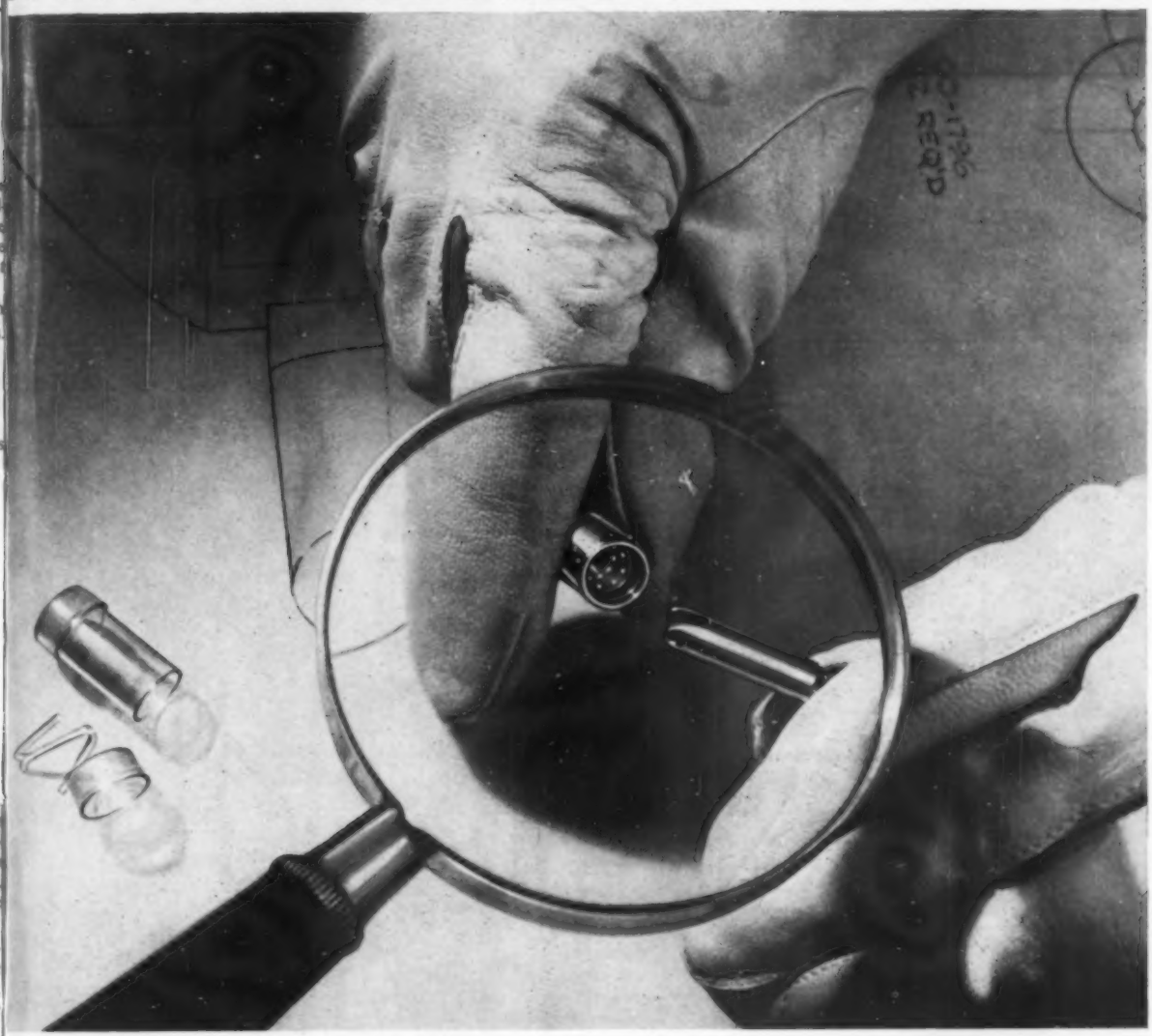
I hope I am not giving away information which might shake the faith of the readers of MISSILES AND ROCKETS.

Morton H. Mehr
General Manager
Measurement Systems, Inc.
Norwalk, Conn.

No, but you are shaking the faith of the editors in some of their sources.—Ed.

Circle No. 22 on Subscriber Service Card.

NEW DEPARTURES IN MINIATURE



HOW TO GIVE ON-THE-NOSE GUIDANCE TO MODERN "FISH"

UNIQUE N/D LINEAR MOTION BEARING FREES GYRO CAGING ACTION

The bearing illustrated is an N/D linear motion precision instrument ball bearing. It was specially designed and built to help solve a critical problem in the guidance system of a high speed anti-submarine torpedo.

PROBLEM: Loss of accuracy in torpedo's guidance system due to hang-up of caging arm in gyro assembly.

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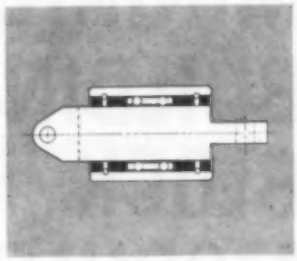
Should you require ball bearing design information, invite the local N/D Sales Engineer to participate in your early design discussions. He represents one of the industry's largest engineering staffs devoted exclusively to the design and development of miniature and instrument ball bearings. Or, write for new Miniature and Instrument Ball Bearing Catalog, Department L.S., New Departure, Division of General Motors Corporation, Bristol, Connecticut.



This special N/D linear motion instrument ball bearing increased guidance reliability of ASTOR torpedo weapon system developed by Westinghouse.

NEW DEPARTURE
MINIATURE AND INSTRUMENT BALL BEARINGS

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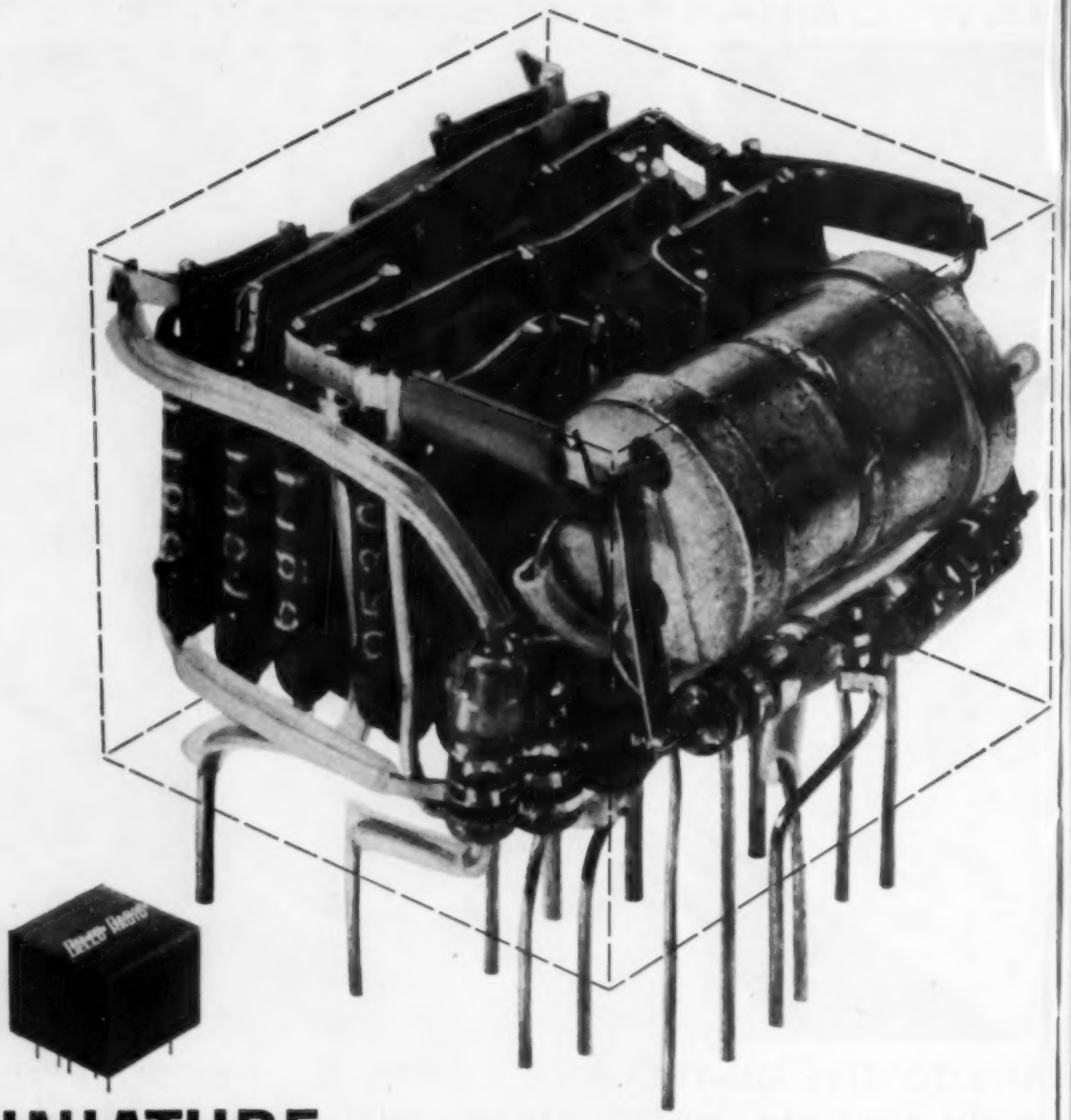

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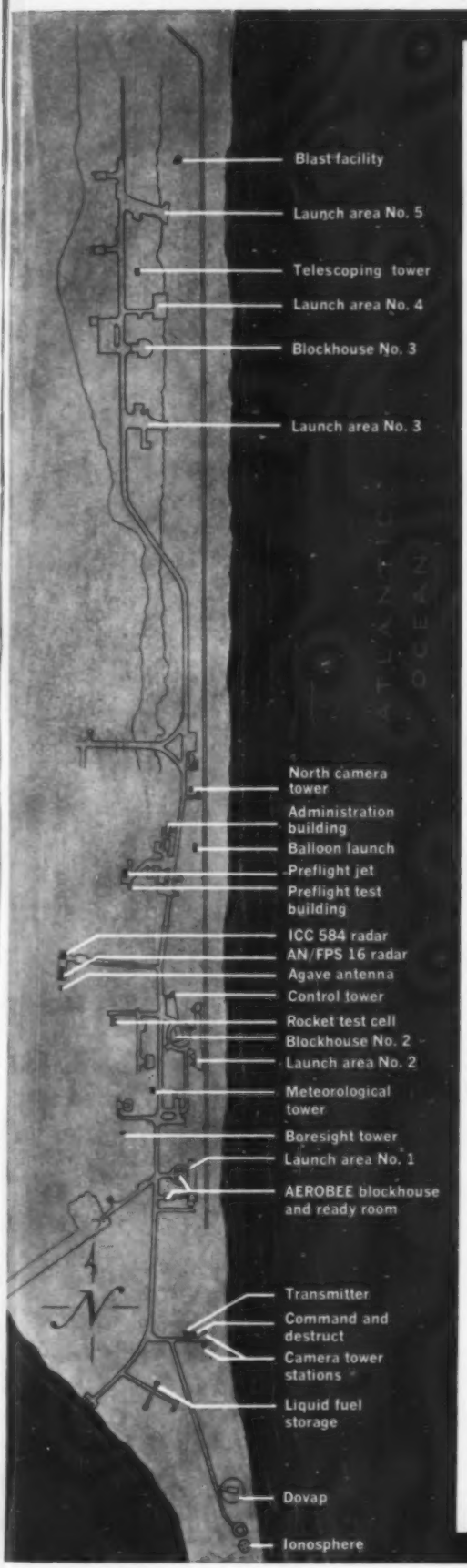

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NASA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The MIDAS* early-warning satellite system orbits infrared scanners to detect enemy missiles at launch. This IR equipment, with its display and control console, is a development of the Avionics Division of Aerojet-General.
Aerojet's contribution to the MIDAS program is an example of proved capability in
• INFRARED • ELECTRONICS
• ELECTRO-MECHANICS • OPTICS
The Avionics Division has under development other reliable systems for satellite instrumentation, missile guidance, target detection, and homing. Current research projects include complete payload packages for an advanced MIDAS, participation in the MARINER program for Venus and Mars exploration, and AEROBEE space experiments.
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Engineers, scientists—investigate outstanding opportunities at Aerojet

The Countdown

WASHINGTON

Has AF Lost Counterforce Fight?

The Air Force appears to have failed to sell the Kennedy Administration on building a Missile Age Counterforce—a strategic striking force capable of prevailing in a nuclear war even after absorbing a surprise attack. Instead, the new Administration is now expected to buy a strategy of beefed-up minimum deterrence along with more limited war forces—particularly for the Army. Meaning in terms of hardware: Some more big strategic missiles, but the big slice of the expected $2 billion increase in defense spending will go to the tactical systems.

Will Dyna-Soar be Speeded Up?

ARDC is understood to be looking over proposals to more than double spending on *Dyna-Soar* and to get the space bomber operational sooner by going direct to manned orbital flights. Project officers say 19 months could be saved by skipping the first step—manned suborbital flights. This would make an orbital flight possible as early as 1963. Funding for FY '62 is $70 million under Eisenhower's budget. Acceleration would require jumping this to $150-200 million.

NASA Cancels Atlas—Temporarily

COUNTDOWN hears NASA had a cancellation order on all plans for using *Atlas* boosters beyond the *Mercury-Atlas 3*. The order apparently was rescinded after the Feb. 21 success with *MA-2* (see p. 80). It is understood the cancellation was put into effect following the Wiesner Committee suggestion in January that NASA consider switching to *Titan* because of repeated failures with *Atlas*-based vehicles.

Mercury—What Next?

NASA officials are having a tough time deciding the next step in the *Mercury* program. Up for debate: Is another *Redstone* flight needed to determine whether the booster malfunction in the chimp-carrying *MR-2* has been corrected; whether another capsule flight is needed to settle the leakage problem, and, if there is another, should it carry a chimp or go empty?

Tiros Shot Moved Up

NASA is advancing the next *Tiros* shot to the second quarter of this year. This third weather satellite had been scheduled for the third quarter. *Tiros-4* has been added to the program and will go early next year. *Tiros-3* was moved up by bumping an *S-3* radiation satellite from a sixth *Delta* vehicle.

INDUSTRY

Wet Blanket for Big Solids

Top Air Force R&D officials are taking a dim view of industry claims of being capable of developing quickly multimillion-pound-thrust solid boosters. The officials say current studies of the future for huge solids are encouraging but still tentative. Moreover, they think it would be a mistake to fail to exploit the possibilities in developing medium-size solids first.

Sensing Solid Rocket Failures

NASA is sending out a call for information to help man-rate big solid rockets. Solids Rocket Chief William Cohen wants to know where solids "telegraph" impending failure so that sensors can be placed to actuate an escape system. Cohen may award a study contract shortly.

Aluminaut Decision Near

Office of Naval Research will decide within three weeks whether to go ahead with *Aluminaut*—the all-aluminum submarine for deep ocean research. The Reynolds Metals Co. proposal has been under study and design by Southwest Research Institute for two years. If Navy agrees to a long-term leasing arrangement, the sub will be built by General Dynamics' Electric Boat Division under a 1962 completion date.

Redeye and Mauler Starve for Funds

Two hot Army projects—Convair's *Redeye* and *Mauler*—are suffering from serious fiscal anemia. The Army says both are undergoing painful stretchouts. For example, *Redeye* is now expected to slip about one year.

Along Mahogany Row

Washington, D.C., industrialist William C. Foster is the new board chairman of Aerospace Corp., succeeding Roswell Gilpatric, who became deputy defense secretary. . . . Prospective merger between American Electronics and Electronic Specialties is understood to be off. . . . Thiokol expects sales to go over $200 million in 1961 and profits to improve substantially. . . . Stockbrokers are recommending Lockheed, Martin, North American, Northrop, Aerojet-General and Republic Aviation for their "near-term speculative appeal."

INTERNATIONAL

That Date With Venus

Estimated arrival of the Soviet space probe at Venus is now back at the original time—the last two weeks in May. Reports (M/R, Feb. 20) that the probe would arrive in mid-April are being attributed by the Russians to some garbled interpretations by a Soviet science writer, Harry Shternfeld.

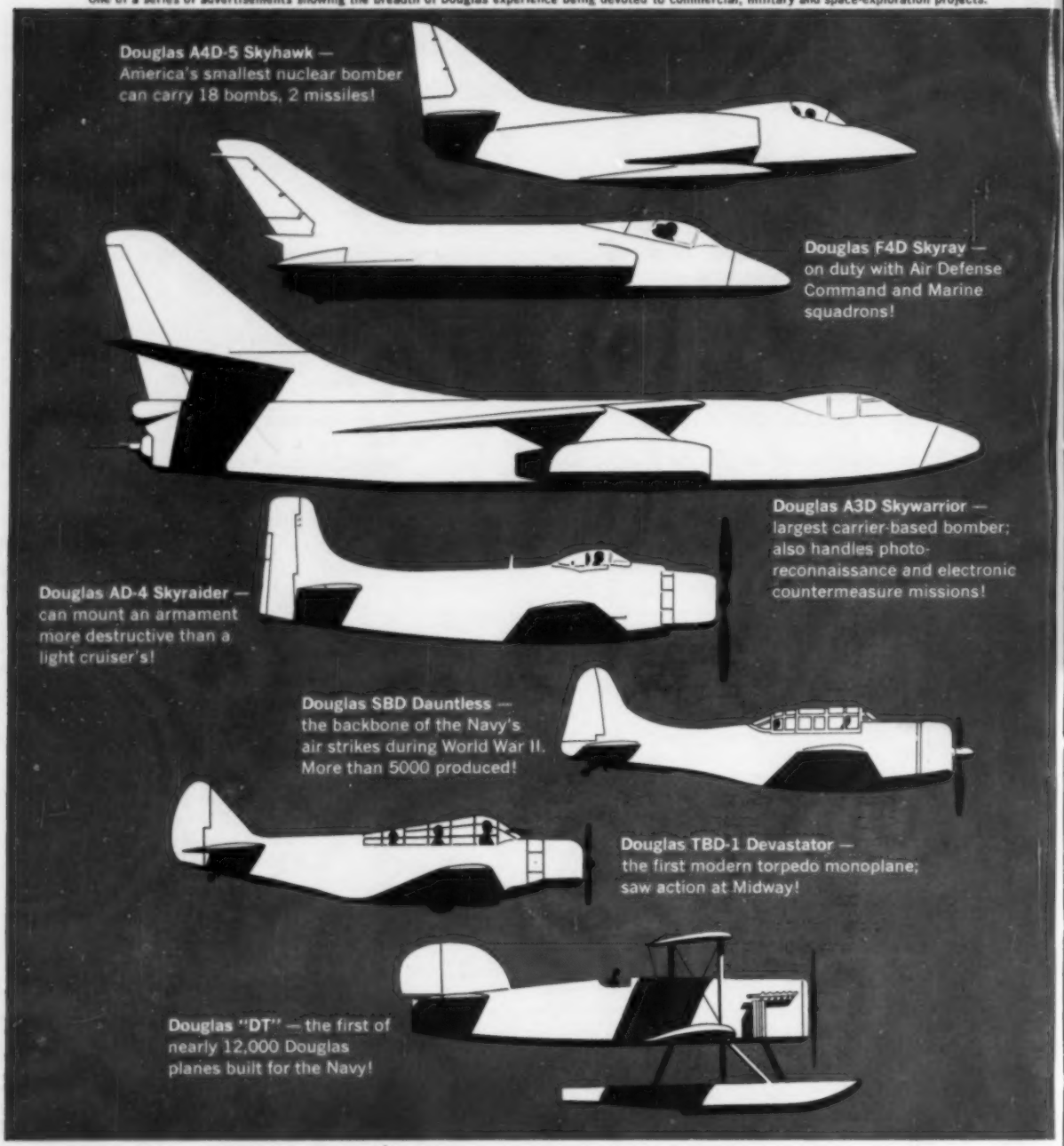
Shuffle in Tracking Sites

There may be some new *Mercury* tracking sites, and some older U.S. tracking stations around the world may be dropped. Word is out that NASA/STL crews are being returned from Jodrell Bank and also from the Singapore site. Woomera is expected to become a key station in future operations.

Overseas Pipeline

Five more high-altitude probes (around 1100 mi.) are planned by Italian scientists from the Perdasdefogu range on Sardinia using U.S. sounding rockets. . . . A French white rat named Hector survived a 95-mi. ride into the atmosphere Feb. 22 aboard a *Veronique* launched from Colomb-Bechar. . . . New Soviet MIG-21 Mach-2-plus fighter is said to be armed with four advanced *M-100 A* IR guided air-to-air missiles.

One of a series of advertisements showing the breadth of Douglas experience being devoted to commercial, military and space-exploration projects.


Douglas A4D-5 Skyhawk — America's smallest nuclear bomber can carry 18 bombs, 2 missiles!
Douglas F4D Skyray — on duty with Air Defense Command and Marine squadrons!
Douglas A3D Skywarrior — largest carrier-based bomber; also handles photo-reconnaissance and electronic countermeasure missions!
Douglas AD-4 Skyraider — can mount an armament more destructive than a light cruiser's!
Douglas SBD Dauntless — the backbone of the Navy's air strikes during World War II. More than 5000 produced!
Douglas TBD-1 Devastator — the first modern torpedo monoplane; saw action at Midway!
Douglas "DT" — the first of nearly 12,000 Douglas planes built for the Navy!

Douglas refined 40 years of experience into versatile Navy Skyhawk

The new Douglas A4D-5 Skyhawk – a powerful ace-of-all-trades for the Navy – is the result of the same imaginative engineering that has brought Douglas to the forefront in commercial aviation and the push into outer space.

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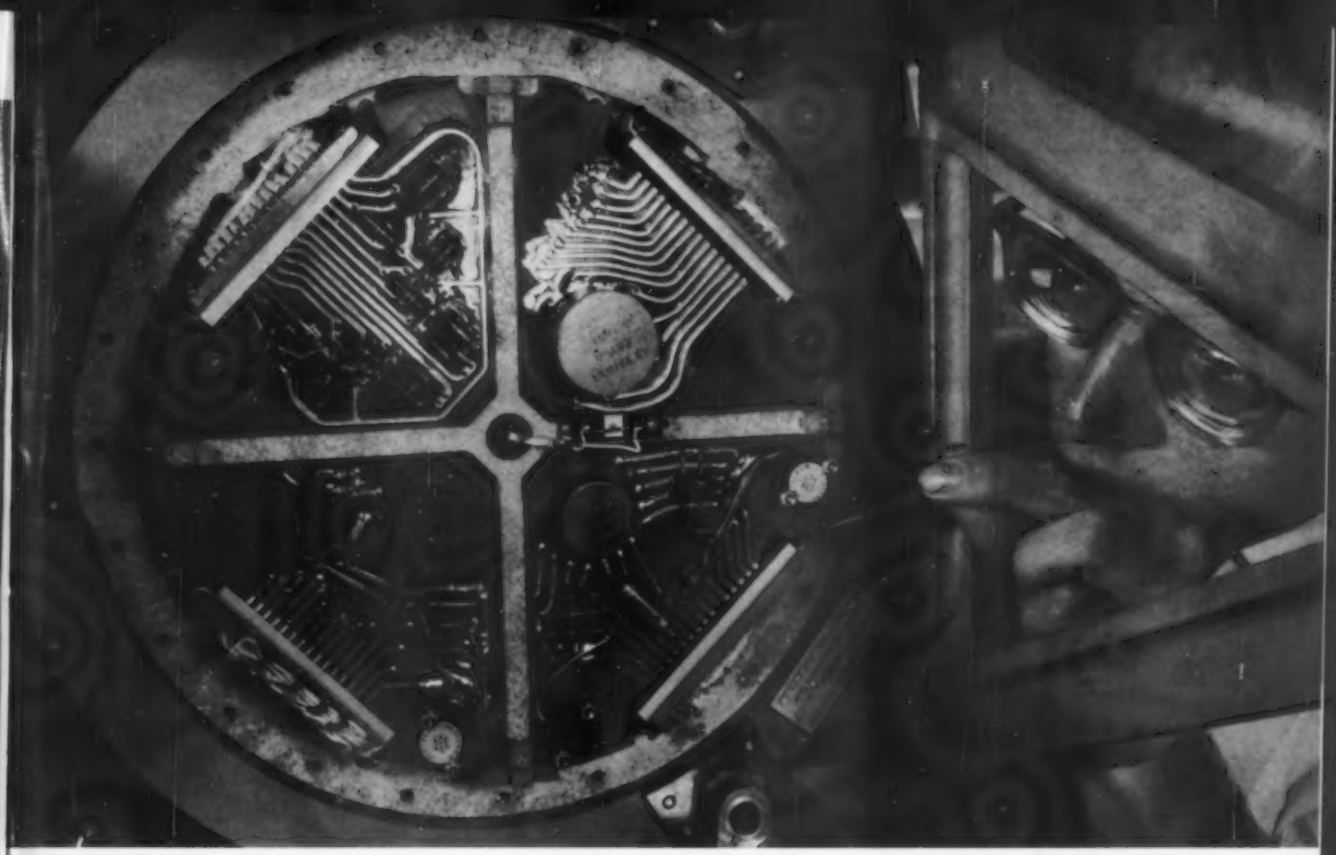


Honeywell's Scout guidance

M/R's 4th Annual Electronics Issue

Today, expenditures for guidance and control systems are commanding 20 per cent of all production dollars for missiles and spacecraft. The G&C market—already at $1 billion—is expanding rapidly. What are the powerful trends affecting this large segment of industry? Missiles and Rockets on the following pages presents the first careful analysis of the guidance field—including the first published breakdown of where the money is being spent now in missiles and space systems. And there's more in this special issue. The first complete roundup of gyro research and development; an 11-step program for improving guidance computers—plus:

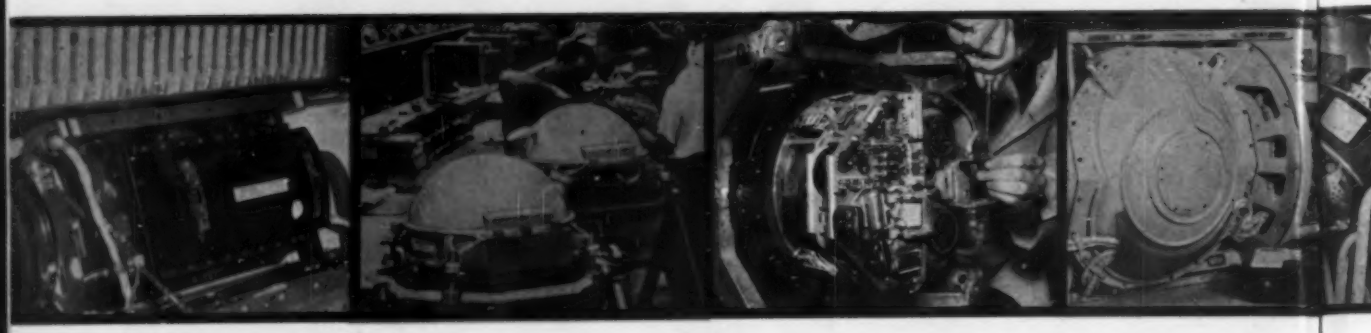
- ***Exclusive technical descriptions of an advanced inertial system for Atlas and the guidance packages going into Minuteman and Titan II.***

- ***First complete report of integrated G&C for manned space vehicles.***

GUIDANCE/ *MARKET OUTLOOK*

Space Systems Will Lift G&C

by Charles D. LaFond



Inertial packages for missiles are expected to command 60% of $506 million to be spent by '65; biggest changes revolving about thrust/aerodynamic flight controls

THE MISSILE/SPACE guidance and control market—excluding GSE—is nearing the $1 billion mark for 1961 and is expected to pass $1.5 billion by 1965.

As in any healthy market, changes are occurring which will alter the face of the industry: inertial guidance systems are on the increase, radio command systems are being de-emphasized, thrust and combined aerodynamic/-thrust control systems will slowly increase, while aerodynamic controls steadily diminish.

Technologically, the industrial parents of this young giant feel that it could use some rapid readjustment. It has grown from inadequacy to overcomplexity in less than 15 idea-ridden, ambition-bitten years. Manufacturers have digitized, stellarized, miniaturized, transistorized and ruggedized; yet there still is a pressing need for greater reliability, sensitivity, producibility, and storability. Higher accuracy and lower costs would be welcome, too.

Nevertheless, such a vibrant industry can support the research effort necessary to solve these problems and even create new ones. Solutions are running about even with creations.

• **Strong market increase**—In its survey of over 100 G&C systems and components manufacturers, M/R received estimates as high as $2 billion for 1961. However, a conservative spread of from $730-900 million appears more realistic. This works out to be about 20% of the missile production dollar. A 50-60% increase in the whole market (see table I) is forseen by 1965.

This amounts to about a 15% maximum increase each year which exceeds the anticipated 10%/year rise for the electronics market in general.

Dr. W. F. Ballhaus of Nortronics predicts that during the next 5-10 years guidance system R&D will account for up to 60% of total systems R&D. He bases his forecast on current demands for improved reliability and accuracy. However, he feels that as guidance systems go from R&D into production, guidance costs will drop to 30-35% of total expenditures. Others in industry agree.

The greatest problem in determining size of the market is in defining the market. Figures shown above refer to G&C systems, spares, RDT&E plus directly associated support systems. It is the "associated" equipment that clouds all estimates.

A general feeling exists among the larger manufacturers that as the market generally increases, a weeding-out process will occur. This trend is also true for the entire military and space electronics field. The field is diluted, but those who have failed to keep up in advancing their capability through concentrated R&D will surely be eliminated. Some have died, but this attrition has been counter-balanced by new entrants into the field.

The obvious change in emphasis from radio command to all-inertial guidance will take a toll, but mostly at the first and second tier subcontractor level. The radio-command guidance leaders also are among the inertial leaders. All their bets have been coppered.

• **Guidance trends clear**—A finer breakdown of the missile guidance and control systems field quite clearly reveals the trends for the next few years and probably for the next ten.

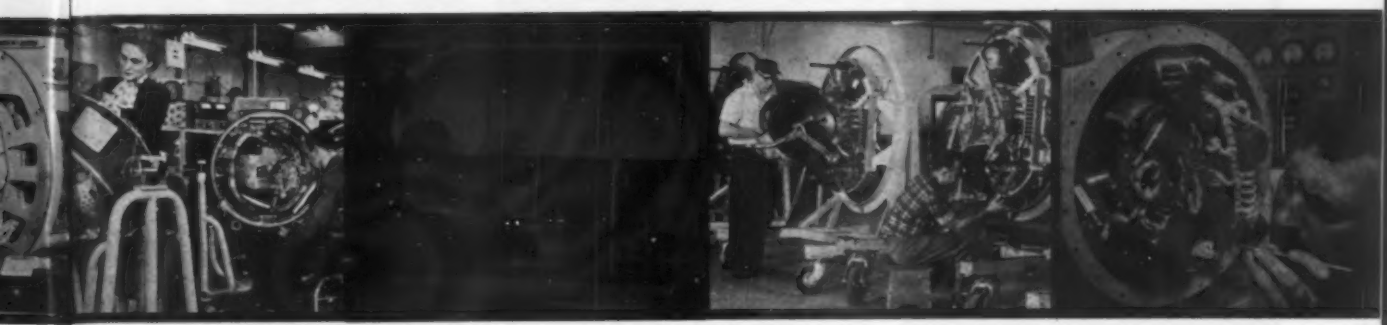
Mr. William Buckley, senior market analyst at General Electric's Light Military Electronics Dept. recently completed an extensive survey of this market. Excluding all associated equipment, and considering only the production costs for the G&C systems, spares R&D, and product improvement for known and reasonably assumed systems, Buckley predicts a total market of nearly $800 million by 1965 (see table II).

He further predicts a 25% increase by 1965 in the missile guidance market, with inertial guidance alone accounting for roughly 60% of the estimated $506 million total. During this same period command guidance, semi-active radar and infrared homing will decrease, Buckley asserts.

There will be some disagreement with the figures and even some of the trends reflected in table II. For example, several manufacturers closely approximate G.E.'s 1961 inertial guidance figure with its estimate of $265 million, but they also predict a '65 market of up to $475 million—or roughly $130 million more. Others predict even more growth.

Another area of sharp disagree-

...Market to $1.5 Billion



ment is in the realm of optical and infrared guidance. Aerojet—General's Avionics Division did $8.2 million of business in this field in 1960, expects to reach $20 million in 1961, and $50 million by 1965. Others in the IR field concur. (More on infrared expectations later.)

The total missile control system market, according to Buckley, will decrease by $175 million through 1965. This heavy fall, he feels, will be caused primarily by a decease in procurement of missiles using costly aerodynamic control systems. (A sizeable production order for *Nike-Zeus* might alter this situation since it employs both aerodynamic and thrust control.)

Thrust control systems will certainly continue to increase steadily while the trend upward of reaction control at the present time is almost insignificant. These systems will enjoy increased use only when there exists a greater volume market for satellites and spacecraft.

• **All-inertial flourishes**—The market picture for missile/space inertial guidance systems as indicated above is one of assured and continuous heavy growth. Total estimate for 1961 is about $300 million; $475-500 million is expected by 1965.

Inertial guidance for space use offers the biggest question mark. For 1961, it is expected to fall between $4 and 6 million. Space inertial guidance use by 1965 is estimated wildly between $14 and 30 million. A more definite figure just isn't available.

Minneapolis-Honeywell, Arma, G.E., Autonetics, AC Spark and Bendix appear to hold a strong lead in this field. Their contracts on hand account for all of the funded large military/-space systems. General Precision, Inc., Lear, and Sperry Gyroscope fall in line next with a variety of current programs. Hughes, RCA, Raytheon, Reeves Instrument, and Motorola have the capability and are ready to leap into the first open spot available.

LEFT TO RIGHT: Atlas-D radio command G&C, developed by General Electric; Atlas-E all-inertial platform (and system), developed by Arma; Titan I gyro reference, built by Honeywell for BTL radio command system; Polaris A1 inertial platform (and system), developed by MIT and General Electric; Thor all-inertial platform (and system), developed by AC Spark Plug; Delta radio command G&C, developed by Douglas Aircraft and BTL; Mace-A terminal map matching system, developed by Goodyear Aircraft; Scout inertial platform (and system), developed by Honeywell.

Nortronics stands practically alone in the stellar-inertial field. It has pioneered in this field with *Snark* and now with *Skybolt*.

Daystrom, Summers Gyroscope, Bell Aerospace and Norden Div. of United Aircraft have been major suppliers.

It is also interesting to note that Minneapolis-Honeywell has a commanding lead in space vehicle guidance systems for 1961 (above 60%).

One point must be considered when discussing almost any type of guidance system and that is the tremendous in-house capability that exists among all of the large primes. Martin, Boeing, Douglas, Convair, Chrysler, McDonnell—any of these could break into the market as a subcontractor or associate prime, as Lockheed Electronics and Autonetics have done. Such a move could cause considerable reshuffling of rank in a relatively short time.

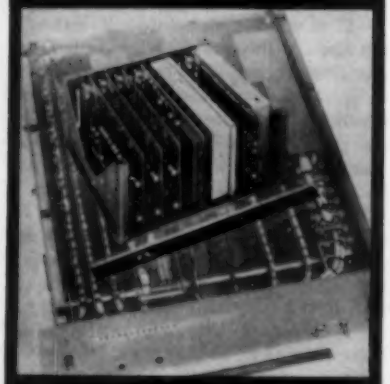
• **Radio command dwindles**—The Air Force has made no attempt to disguise its delight with inertial systems and the down-grading of emphasis on radio command guidance. Its *Thor, Hound Dog, Mace-B, Snark,* advanced *Atlas* and *Titan, Minuteman, Skybolt,* and *Dyna-Soar;* the Navy's *Polaris* and *Regulus II*; the Army's *Jupiter, Pershing, Redstone* and *Sergeant* are all medium to intercontinental range ballistic missiles and all use inertial forms of guidance.

Command systems found immediate use in the early *Atlas* and *Titan* models. These will be phased out. Other major systems employing command guidance are: (Air Force) *Bomarc A* and *B, Thor-Delta, Thor-Able-Star* boosters—although both use radar homing, *Bullpup*—via visual reference, *Matador*; (Navy) *Regulus I* and *II*; (Army) *Corporal, LaCrosse,* and *Nike-Ajax, -Hercules,* and *-Zeus. Bomarc-B* production has been curtailed; production has stopped for *Bomarc-A, Regulus I, Corporal, Nike-Ajax* and possibly *Nike-Hercules.*

Only *Nike-Zeus* offers a sizeable market potential. (*Typhon* is still a question mark. It reportedly will use command guidance with a seeker).

• **A transluscent market**—That portion of command guidance systems carried in the bird is fairly discernible—a total of roughly $45 to 50 million in 1961. This is expected to drop to about $25 million for 1965.

But, by far the greater portion of



such systems is located on the ground. Radar transmitters, receivers, antennas, computer complexes, etc. These are big and costly.

The problem is where or how do you separate guidance from detection, discrimination, and target tracking processes. The market then merges with those of data processing and detection and tracking.

Not one guidance manufacturer contacted in this survey would hazard a guess. Neither shall we. Let it suffice to say that (1) it has been very big business (hundreds of millions), (2) it is a vanishing market today, and (3) a quantity production order for *Nike-Zeus* would return it to a top market position.

Leaders in this segment of the guidance field are Western Electric and Bell Telephone Laboratories, Sperry Gyroscope, Westinghouse, General Electric, Martin, Federal Div. of ITT, Lockheed Electronics Div. (formerly Stavid Engineering), and Kearfott Div. of GPI. Raytheon, Motorola, Sylvania, Philco, Stromberg Carlson, Texas Instruments and Litton Industries have been important suppliers.

• **Radar trends—up and down**—Active, semi-active, and passive radar homing represent another large slice of the guidance system pie.

Active radar (employing a missileborne radar transmitter and receiver) is relatively small today, but the trend looks like a sharply increasing market for the next few years with a growth from some $2 million in '61 to possibly $30 million by '65.

The reason is the same as for inertial systems—comparable accuracy, lower (eventual) total cost with negligible ground support requirements. Current systems include *Bomarc-A* and *B* (terminal guidance), *Eagle*, *Falcon-1 D* and *-3*, *Sparrow III*, *Sidewinder 1-C*, and possibly *Typhon* (terminal guidance).

Leaders are Kearfott, Westinghouse, Philco, Bendix, Hughes, Raytheon, and Motorola.

Semiactive systems (target illuminated by a radar transmitter external to the missile, such as beam riders) appear to be following a downward trend: $80-85 million, 1961; $45-50 million, 1965.

Raytheon, Farnsworth, Sperry Gyroscope, Reeves Instrument, Federal Div.-ITT, and Westinghouse have led this field with systems in *Hawk*, *Talos*, *Tartar*, *Terrier*, and *Advanced Terrier*.

Passive radar guidance (homing on radar emissions generated by the target) is another market question mark. The Air Force *Arm* is a conceptual missile which has been studied for anti-radar air-to-surface use. Also, the Navy's *Cobra* is in early R&D for use against shipborne radar targets. No contracts have been awarded yet, but Martin, General Electric and Westinghouse are believed to have small company-sponsored R&D programs in this field.

• **IR market changes**—Opinions vary widely on the trends in the infrared market. It may be a case of the Haves vs. The Have Nots.

As indicated earlier, many predict pure IR homing as a decreasing market. The IR people say no. Most agree that hybrid IR/Radar homing systems are coming into their own during the next five years.

If the latter reach $20 million by 1965 or 1966 as has been predicted, this will represent a rapid growth and require volume production. This estimate only considers missileborne equipment and such systems are relatively inexpensive.

IR homing (passive use of thermal radiation from the target) is presently used in the *Falcon GAR-2* and *-4*, *Mauler*, *Redeye*, *Sidewinder*, and possibly *Shillelagh*. Hughes, Philco, ACF Electronics Div., Aeronutronic Div. and Motorola are systems suppliers.

The *Falcon GAR-9* and *-11* both employ hybrid IR/radar homing developed by Hughes.

Other important suppliers include Avionics Div.-Aerojet General, Chicago-Aerial, Eastman-Kodak, and Westinghouse.

Significant breakthroughs in IR system development could change the picture. One in particular is receiving considerable attention by Boeing, Bell Telephone Laboratories, Raytheon, G.E. and Westinghouse. They reportedly are concentrating on developing IR homing for AICBM's such as *Nike-Zeus*.

• **Map matching to gain**—Significant increase is predicted for terminal map-matching guidance systems from around $5 million in 1961 to about $35 million by 1965.

Used in *Mace-A*, the only operational system existing today was developed by Goodyear.

It may find use in future surveillance and target drones or new missiles now under study.

• **Other systems**—Radiometric homing systems may possibly be employed in the future. These home on thermal

TOP TO BOTTOM: SOLO stabilized optical guidance system, developed by Chicago Aerial; G.E. electrostatic gyro operated for continuous periods over 100 hours; Honeywell electrostatic gyro may see use in Polaris-sub navigation; new missileborne analog-to-digital converter size cut by Packard-Bell; Vinco and Fecker sidereal rate stands test Atlas-E inertial platforms.

radiation (from a target) in the microwave range. Other passive seekers in the radio frequency and ultraviolet portions of the electromagnetic spectrum are being studied by Martin, RCA, Westinghouse, G.E., and Motorola.

• **Gyro market large**—Total market estimates for missile gyros and accelerometers including R&D vary from $275 to $300 million for 1961.

(A very complete state-of-the-art roundup of gyro technology by Mr. B. Lichtenstein of Kearfott, appears on p. 21. The article provides an unusually detailed picture of current development and future research trends.)

In general the gyro leaders are also the top producers of accelerometers. Dollarwise and in total number of units sold, two manufacturers stand out: Minneapolis-Honeywell and Kearfott. Between the two companies they have placed their guidance sensors in almost every missile and space system, past, present, and near future.

Those who are nearly as big in dollars and number of units—but largely because of captive markets—are Raytheon, Arma, General Electric, Autonetics, Nortronics, Bendix, Ford Instrument and Sperry Gyroscope, AC Spark, and Westinghouse.

Others who have done well in number of units (all types) include Lear, Whittaker Gyro, Reeves Instrument, Summers Gyro, Daystrom, Bell Aerospace, Giannini, Sanders Associates and Norden.

The gyro industry may see a marked change in this lineup in 5 to 10 years. There are many exotic gyros now in development—some of these may die, but others will replace existing types.

Such approaches as electromagnetic or electrostatic suspended systems are aiming for total freedom from friction. There are still many problems to overcome, but these may well be tomorrow's systems.

As we see it now, the penultimate approach could be the nuclear gyro. There is hardly a major producer today who is not investigating this concept—the use of magnetically alined atomic nuclei to create a gyroscopic sensor.

Accuracies of the order of 10^{-6} degree/hour are believed possible with such an approach.

How close are we to development of such a system? Dr. R. L. Garman, vice president for R&D at General Precision Laboratories, flatly predicts that a nuclear gyro will be developed and in use experimentally within 5 years.

• **Healthy computer market**—Currently, the missile guidance computer market is about $130 million. However, with the trend toward more and more inertial systems, these subsystems must also follow a parallel curve upward. By 1965, the market is expected to reach $185-200 million with R&D decreasing and production increasing.

It represents a good potential market segment for the vast computer industry. Yet, as has happened in so many other areas of the electronics industry, those who got in first probably will remain at the top.

Manufacturers such as Librascope, General Electric, Arma, IBM, Bendix pican Corp. for use in the *Polaris* guidance computers, will have a marked effect on the industry.

National Cash Register Co. also is making progress with its photochromic memory research. Responsive to light, these chemical cells offer promise of computer memories of unprecedented density for space use.

(A roundup of computer research trends is provided by Mr. R. R. Williamson of Librascope on p. 24).

• **Control systems**—Except for General Electric, Minneapolis-Honey-

*Table I—Estimated Guidance, Control, and Associated Systems Expenditures for Missile/Space Vehicles**

(In Millions of Dollars)

Market	1961	1963	1965
Total G&C—Missiles	640-800	889- 895	996-1,120
Total G&C—Space Vehicles	090-100	235- 250	490- 600
TOTAL	730-900	1,124-1,145	1,486-1,720

**SPREAD REPRESENTS typical high and low figures of all industry estimates obtained from M/R survey of the field. Figures include expenditures for G&C systems, research and development plus directly associated external and support equipments, such as ground data processing, displays, and checkout, star trackers, etc. See Table II for complete breakdown of missile G&C systems only.*

and Autonetics hold, by far, the majority of contracts in this field. Their current R&D efforts indicate they intend to control the future market, too. Texas Instruments, Martin, Western Electric, and Motorola are doing well with guidance programers.

The trend so far has been for companies having guidance platform experience to also acquire computer contracts, although not generally for the same programs.

Sperry Gyroscope, AC Spark, Nortronics, Hughes, Packard Bell, Minneapolis-Honeywell, and Federal Div. of ITT with their present contracts have developed a capability and could snatch more of the market at any time.

Burroughs and RCA may be sleepers. So far they haven't really broken into the market, yet they have the hardware and R&D capability to move forward once they do break in.

And there are always going to be companies who make a component breakthrough that could catapult them into this field, such as Aeronutronic and Melpar with their work in artificial "nerve networks." Both have made significant bionics gains in developing electronic nerve cells for "thinking" machines.

The Miniweld fabrication technique (see story, p. 26), developed by Sip-

well, Sperry Gyroscope, and Lear, missile/space control systems are in general held by the missile or guidance primes.

This is due largely because of the nature of the beast—a combination of electronics, hydraulics, and mechanics married to a frame, propulsion and guidance systems.

Total missile/space controls market for 1961 is estimated to be $300-360 million.

Table II shows a declining market for missile aerodynamic control and a steady increase in missile thrust control. There also will be a growing need for combined aerodynamic and thrust control systems.

Several adaptive electronic flight control systems are in advanced development by Sperry, G.E., and Honeywell. All are designed for use in aerospace-type manned vehicles.

Sperry has the integrated G & C system for *X-15*, while Honeywell's system is being developed for *Dyna-Soar*. G.E.'s system was developed under a WADD contract for aerospace use and will be tested in the *X-15* as will the first Honeywell system.

Lear controls are used in both *Pershing* and *Polaris*.

• **The part of testing**—The gyro test equipment role in producing guid-

ance systems is one whose importance and accuracy has grown with the rest of the industry.

In the 10 years following World War II, a 1000:1 improvement was made in the gyroscopic art. Now, many believe that additional 100:1 improvements will be made just over the next few years.

Specialized equipment and techniques are necessary to test such systems. Many were built by the missile and guidance primes simply because there was nothing available or because with modification some equipment could be changed over for the new requirements—centrifuges, special systems for rocket sled testing, electronic checkout gear, etc.

At the same time, specialists were brought in to build and develop operating techniques for super accurate gyro test and measurement. Thus, the gyro test table and electro-optical measurement devices came into prominence.

Two manufacturers, J. W. Fecker Div. of American Optical Co., and Vinco Corp., largely control the test table market.

As a measure of accuracy, gyro error is described by a drift rate. World War II gyros had drift rates in the order of 10°/hour. The gyros developed in the 10 years following the War and in use today, have a drift rate of the order of 0.1 to 0.01°/hour. Gyros under development today, but not yet in production, are expected to have drift rates of 0.001 to 0.0001°/hour.

The older 10°/hour gyros were tested by simply allowing them to sense rates or positions. Rates were produced by simple turntables having accuracies of the order of 1%. Displacements were produced by simple gimbal mechanisms and modified rotary tables. Accuracies of ½° were sufficient.

Equipment for test of present day gyros, according to Mr. J. Colker, chief engineer at Fecker, can produce rates with short term errors of 0.1% and long term errors of 0.005%. These devices, he said, are used to generate rates to be measured by the gyro and at the same time cancel out the earth's rate. In this measurement, gyro torquer current must be determined accurately (about 0.01%).

Test devices that rely on position measurement today have accuracies of ±1 second of arc. Such devices have glass discs with lines scribed every 0.1° and are read photo-electrically.

These, Colker feels, are adequate for present day testing. Today, in measuring a drift of 0.01°/hr. in earth's rate (15°/hour) we are looking at effects of approximately one in 1000 with a measuring instrument that is at least as good as one part in 10,000, or 0.01%.

For future testing Fecker would like an instrument accuracy of 0.0001% or one part in a million. Present rate generating and current measuring devices are far short of this goal. The Fecker position measuring device almost has this accuracy as long as the errors are distributed over 360°. Unfortunately, this is often not the case. Even more unfortunate, Colker said, is the difficulty in measuring errors smaller than 1 second, because so very often the error distribution is not known.

Existing accurate rate-generating devices use worm drives with long-term errors of ±3 seconds of arc, and short-term errors of ±1 second of arc.

Fecker is now developing equipment which requires the generation of rates to a short-term accuracy of 0.01%. To meet this tolerance an "electronic gear reduction" is used. Control of this system is completely digital.

Along with the development of high accuracy position and rate digital measuring systems, there is also a trend toward completely automatic testing.

Because of the large amounts of data produced in gyro test imposing a heavy burden of data recording and evaluation the majority of test equipment produced is semi-automatic. In these devices readout of data is automated and provided in a form compatible with general purpose digital computers.

The manufacture of gyro test devices requires that angles be measured to extreme accuracies usually to a second of arc or less. This measurement is accomplished optically using theodolites, autocollimators or interferometers. (See M/R Optics Report: Aug. 22, 1960.) These measurements must be made under stable temperature conditions in areas of extremely low vibration.

• **Normal problems persist**—Reliability and accuracy lead everyone's list of problems associated with today's guidance and control systems. Of the manufacturers responding to M/R's survey of the field, 100% included these two items in their tabulations of improvement needs.

Equipment size, weight, cost, and sensitivity are the next most serious problems. Others feel system complexity is high on today's list of critical items.

Fred Stevens, Nortronics' pioneer guidance expert feels: "We are forcing performance with complexity. We've reached the point where a more mature approach to simplify systems is needed." Dozens of other leaders echo his belief.

Here are some of the other chief problem areas:

–Materials. Thermal and creep properties, especially in metals under tension, are a heavy contributor to gyro

(Continued on page 57)

*Table II—Estimated Guidance and Control Expenditures by Missile System Type**

(In Millions of Dollars)

Market	1960	1961	1963	1965
GUIDANCE SYSTEMS:				
Radio Command	52	44	28	25
Inertial Guidance/Reference	141	234	345	346
Active Radar Homing	2	2	20	31
Semiactive Radar Homing	94	81	64	48
Passive Radar Homing	1	2	(?)	(?)
Radar/Infrared Homing	3	5	10	18
Infrared Homing	20	22	10	2
Radiometric Homing	...	...	(?)	(?)
Terminal Map Matching	5	4	14	36
(1)Subtotal	318	394	491	506
(2) Research & Development	137	146	104	97
TOTAL	**455**	**540**	**595**	**603**
CONTROL SYSTEMS:				
Thrust	17	22	23	26
Aerodynamic	178	188	143	117
Reaction	1	1	1	2
(3) Subtotal	196	211	167	145
(4) Research & Development	28	24	16	15
TOTAL	**224**	**235**	**183**	**160**
Total G&C Systems (1, 3)	514	605	658	651
Total G&C R&D (2, 4)	165	170	120	112
TOTAL	**679**	**775**	**778**	**763**

**DATA COMPILED in this table were provided largely through the efforts of Mr. William Buckley, Market Analyst in General Electric's Light Military Electronics Department, Utica, New York.*

Gyros Of All Types Face Change In Design

by Bernard Lichtenstein

Mr. Lichtenstein, a nationally known expert in the field of advanced inertial sensors and systems, heads the Applied Research Laboratory, Kearfott Division of General Precision, Inc.

GYROSCOPIC DEVICES in the immediate and foreseeable future will continue to be the most convenient and practical flight reference instruments for attitude and rate sensing.

As a consequence, their use in coming years will continue to grow. However, their specific design and performance characteristics will change.

Gyroscopes encompass a great variety of devices which vary in configuration, complexity, application, performance, and price; but they all share the phenomena of precession and/or inertial rigidity inherent in a spinning, gimballed, rotor.

• **Gyro fundamentals**—Of the many methods of categorizing gyroscopes, one of the most common is to refer first to the degrees of freedom and then to the corresponding function. Accordingly, they are usually referred to as single-degree-of-freedom or two-degree-of-freedom gyroscopes.

Although within each category there are a great variety of design features and fabrication schemes, almost every gyro can be fitted into one of these two categories.

Single-degree-of-freedom gyros include two general types:

Rate: its output from the precession axis is directly proportional to rate sensed by the gyro input axis;

Rate integrating: its output from the precession axis is directly proportional to the integral of rate sensed by the gyro input axis.

In a rate gyro, the preponderant restraint about the precession axis is spring restraint; in the rate integrating gyro, it is damping.

Two-degree-of-freedom gyros consist of three general types:

Directional: oriented and gimballed so that its output is an indication of azimuth heading;

Vertical: oriented and gimballed so that it has outputs which are indications of vehicle roll and pitch, measured from vertical.

Free: oriented and gimballed so that its outputs are a measure of deviation from an arbitrary initial reference.

The differences between these three gyroscopes are essentially of a mechanical nature—the directional gyro and vertical gyro have vertical references (e.g., bubble switch) as part of their configuration, while a free gyro has some caging scheme associated with it.

• **Stable platforms** — In situations where it is desired to obtain information about three axes with an accuracy beyond that available from simple gyros, gyroscopes are used in conjunction with servoed gimbal loops.

The gyros then need only sense their respective inputs which are used as error signals to control high-gain alignment loops. Whenever it becomes necessary to obtain drift accuracy better than 5 to 7 degrees/hour, the use of a stable platform is indicated.

The performance capabilities of a platform are a function of the gyro sensors. Platforms are usually built with three single-degree-of-freedom rate-integrating gyroscopes or two two-degree-of-freedom free gyros as the reference sensors.

• **From Falcon to Titan**—Gyroscopes are used as sensors of rate and indicators of attitude in missiles ranging in size from the 6-ft. *Falcon* air-to-air missile to the 90-ft. *Titan* ICBM; they guide torpedoes and also the subs firing them; they will guide the high flying B-70 mach-3 bomber as well as low flying, low-speed Army spotter aircraft.

It is apparent that one gyro or even one type cannot fulfill such a wide range of requirements. The range of performance capabilities reflected in anticipated duration of flight, acceptable weight and size, accuracy, and operating environments precludes any universal design.

There is also a continuing demand for improved accuracy. A more accurate gyro can mean a smaller CEP. This can result in a smaller warhead, leading in turn to greater range.

A corollary of greater performance potential, usually, is an increase in severity of environmental conditions.

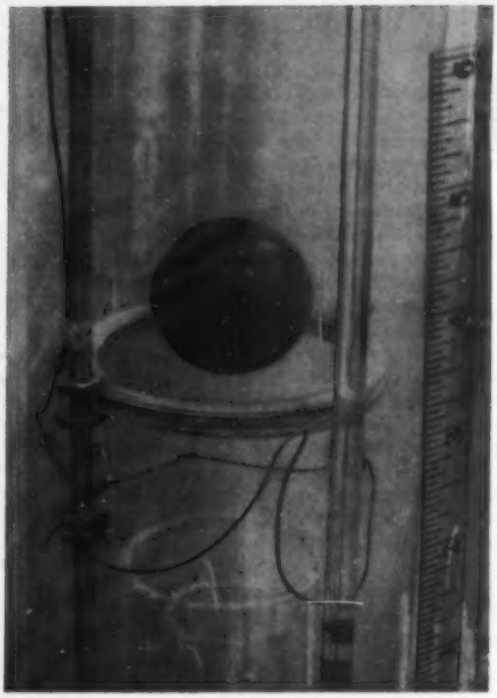
• **Requirements fit mission**—The requirements of missile gyroscopes can be divided into two rather broad categories: (1) low accuracy, severe environment, and low cost; or (2) high accuracy, severe environment, and high cost.

Low accuracy includes gyros with drift rates ranging from 5 degrees/hour to as high as 60 degrees/hour. High accuracy refers to those gyros intended for use in inertial guidance systems; these have drift rates of from 0.10 to 0.001 degree/hour.

The range of drift rates between 0.10°/hr and 5°/hr usually is filled by stable platforms using non-floated type gyros and the range below 0.10°/hr by stable platforms with high accuracy gyros.

Low-cost gyros range in selling price from $200 to $2500 per unit. High-cost, high-accuracy gyros usually range from $6000 to more than $20,000 per

BERYLLIUM sphere, machined by Honeywell to tolerances finer than 14 millionths of an inch, is rotor of electrostatic suspended gyro.



LEFT: *Reductions in resonant gain from 14 to 4 are being achieved by Kearfott with laminated, damped structures. These structures are being incorporated into gyro gimbals to limit drift errors arising from gimbal anisoelasticity.* **RIGHT:** *Lead-coated rotor of an experimental cryogenic gyroscope is shown supported in a vacuum by a magnetic field. Jet Propulsion Laboratory scientists attained this condition by chilling the ball to –450°F. At this temperature the ball levitates above the electrically-charged coil of wire.*

unit. These high-priced units are usually fluid-floated gyros intended for use in high-accuracy inertial guidance systems.

The gap between $2500 to $6000 is usually filled by special versions of the two other categories.

Severe environments, for missile gyros, are conditions wherein the desired drift values referred to must be attained under vibration of 15g, shock loads in excess of 60g, a temperature range of more than 350°F, and bombardment by nuclear radiation, as well as exposure to fungus, dust, moisture, etc.

It would not be far from the truth to state that much of the engineering effort of gyroscope companies today is devoted to attaining current performance capabilities under environmental conditions of increasing severity, rather than improving on performance capabilities. (For example, the cageable free gyro [T2308], developed recently by Kearfott, has a drift rate of less than 0.5 degree/minute under 28g vibration.)

Low-performance, low-cost gyros represent the largest market potential for manufacturers in terms of units if not dollars. While a figure of hundreds of units for a given ballistic missile configuration is optimistic, it is easy to envisage production of thousands of units for the tactical missiles and guided rockets which are rapidly making conventional rifled artillery obsolete.

Such tactical missiles are rarely in flight for longer than 5 minutes, and their flight profiles are essentially two-dimensional. These missiles can tolerate drift rates on the order of 10 degrees/-hour or more in many cases, and their trajectories do not require unlimited attitude capabilities about three axes.

The gyro requirement for such an application is not so much low drift as it is the ability to maintain the desired drift level under sustained acceleration during boost. Also needed are structural rigidity, small size and light weight, ability to operate either from a battery power supply or by a spring-wound motor or pneumatic power supply, and of course low cost. The anomaly of having a gyro cost more than the remainder of the missile is obviously intolerable.

The long-range ballistic missiles and the long-range, cruise-type vehicles, whether unmanned such as the *Hound Dog* or manned such as the B-70, will all require high-accuracy gyros. High performance is essential and high cost must be a secondary consideration.

It is in this area that efforts are being made to improve the level of performance capabilities, and where new techniques of fabrication, materials, and concepts are required constantly.

Also because of their inherently higher performance, the scope of application of these gyros is being widened. For example, where extremely high accuracy is required in the measurement of angular rates, the rate integrating gyro operating in a rate mode (i.e., where the gyro forms a closed loop on itself with its precession output being fed to the precession axis torquer) is replacing the conventional rate gyro.

The overwhelming majority of high-accuracy gyros are used in stable platforms rather than as independent sensors. However, there is growing interest in the use of what are known as gimballess platforms, or body-mounted systems in which the gyros are tied directly to the vehicle flight control system through a computer. (More on this later.) Such a scheme requires the high level of performance attainable only with the high-accuracy, high-cost gyro.

• **Design approaches and trends**—Now let's consider some of the design approaches firms are taking today.

It is important to realize that there can be more than one satisfactory solution to almost any engineering problem, and that the most important aspect of a design is its successful implementation.

A well-thought-out conventional design is preferred to one whose main claim to distinction is its novelty. This is particularly true in missile applications, where reliability is so important.

In the efforts being taken to improve the low-accuracy gyros as compared to high-accuracy gyros, the chief distinction is that the former are largely concerned with refinements and variations upon known techniques whereas the latter are involved in new approaches. However, in due time the advancements in high-accuracy components trickle down in a modified and less costly form to the lower-cost units.

In the two-degree-of-freedom gyros used as vertical, directional, or free gyro references, with performance capabilities of 5-10 degrees/hour, efforts are being made to improve the structural design of the basic configuration.

High g vibration inputs and accelerations create anisoelastic torques and mass unbalances which cause gyro-drift errors. Larger bearings with higher contact angles, used in conjunction with stiffer motor cases, have markedly reduced mass shift errors. But it must be appreciated that the gyro gimbals themselves are capable of anisoelasticity.

Awareness of this is reflected in the changes being made in the shape and material of these gimbals. Laminated, damped structures which are now becoming wide-spread in other areas have been already incorporated in gyro gimbals.

A damped structure limits the resonant rise and transmissibility response of a gimbal and reduces the natural frequency of the structure, at the modest price of increasing the bandwidth of the gimbal structure.

These laminated structures can be layers of similar metal, or alternating layers of dissimilar materials. Resonant gain in gyro structure has been reduced from 14 to 4.

Vibration behavior in some gyros has been markedly improved by the use of classical tuned dampers, which effectively absorb energy from the main structure.

There is an ever-growing trend toward using lightweight aluminum and magnesium alloys to meet the demand for lower weight in airborne equipment. The need for low cost precludes the use of beryllium or other exotic low-weight materials for low-accuracy gyros. However, beryllium does find widespread use in the design and building of high-accuracy gyros.

For extremely short-range missiles requiring gyros, a number of firms have turned to run-down gyros. These are units whose rotors can reach speeds of over 20,000 rpm by the use of a prewound spring or by the discharge of a gas cartridge.

Drift rates exceed 30 degrees/hour, but are satisfactory for the minute or so that gyro performance is required.

Summers Gyroscope and Whittaker Gyro make a large variety of spring-wound gyros; both Lear and Giannini have gas-driven run-down gyros in their product line.

By their nature, these devices are one-shot units, although in theory they may be reused. Their application is limited, but they do have the advantage of low cost.

Where accurate data for a longer interval of time is required, there are some gyros being built or designed for use with a battery supply. Two approaches are being taken. One is the use of a DC gyro motor. The other uses a conventional AC motor operated from a miniaturized solid-state inverter.

• **Future developments** — Looking ahead, preliminary investigations are now being made on gyros which will operate on pneumatic principles, using either a separate hot-gas generator or the combustion products of the solid-propellant booster.

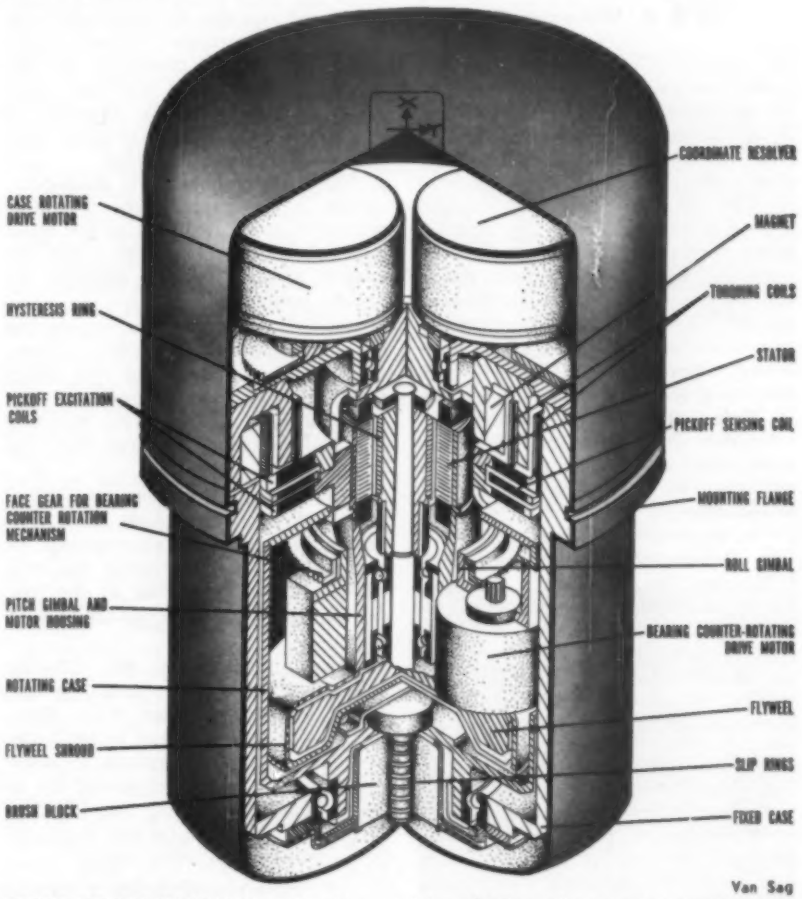
The former approach is being used by Kearfott in both a gyro and a computer element. Diamond Ordnance Fuze Laboratory is using the latter approach for a computer element it has developed.

The advantage of a pneumatic system is the elimination of costly electrical wiring, as well as the ability to operate at higher temperatures without cooling, plus, in some cases (e.g. missiles), a ready supply of energy.

In the field of the gyro rotor itself, the electric motor, particularly the synchronous hysteresis type, remains unchallenged where a constant speed drive is desired. Improved magnetic circuitry using ferrites for the motor is being pursued by Kearfott, as is the use of Hall-effect solid-state devices for output devices.

The Speidel Company is developing

(Continued on page 52)



Van Sag

GYRO PERFORMANCE is being improved by adoption of new error compensation techniques. This is a Kearfott two-degree-of-freedom gyro that employs case rotation about an axis colinear with the rotor spin axis. The technique is designed to average out unbalanced forces about the axis.

INSTRUMENT PANEL for Project Mercury space capsule includes unique instrument called "earth path indicator." Developed by Minneapolis-Honeywell for McDonnell, device is a dead-reckoning computer containing a revolving globe which shows the Astronaut his position in relation to earth, and where he will land when he is ejected from orbit.

GUIDANCE / COMPUTER OUTLOOK

Computer Key to Space Achievement

U.S. manufacturers are proving equal to stringent demands for rugged small instruments; Librascope's Centaur unit is first

by R. R. Williamson*

THE SUCCESS and the scope of man's venture into space will depend on the development of missileborne digital computers to provide vital computation, control and memory functions beyond human capability.

This type of computer exceeds ground-based systems in its requirements for reliability, low power consumption, light weight, small volume, and resistance to severe environmental factors. The instrument must function in a wide temperature range and under severe vibration and g-loads. It must also meet specified computation rates.

Today, these design problems are being met. Digital computers for space application have been designed and produced by many competent U.S. manufacturers.

In its first outer-space application (the *Centaur* computer developed by Librascope Div. of General Precision, Inc.), the digital computer will provide guidance computations and initiate vehicle-control signals.

In the future the computer also will provide control of scientific equipment for experiments performed by unmanned spacecraft soft-landed on the moon, or perhaps on some distant planet. Storage and processing of data from the experiments will then also become a computer task. Missions of this nature may require two or more computers aboard the craft.

When man himself is finally included in the payload, the computer will serve as an auxilliary to the crewman's intellect and, in the automatic control function, it will multiply his muscle power.

At the same time, the engineering of a man into the spacecraft system will impose additional and vital duties upon the computer. Life-support systems will need the automatic monitoring and automatic control that the computer can provide.

• **Genealogy of a computer**—When man makes his first flight in a true spacecraft, he will be accompanied by a computer (or computers) that will trace a family line back to the first digital computers flown successfully in aircraft.

Among these was the CP-209, Librascope's first entry into the airborne digital computer field. Even though this project began in 1952, the division's engineers continue to study this computer under operational use in Navy bombers, knowing that the lessons of today will be the key to tomorrow's problems in outer space.

For instance, since this computer involves a digital differential analyzer, its resolution of navigational problems with respect to real time has a definite relationship to guidance in space.

Further, important lessons were gained in the division's laboratories through the development of the AN/-ASN-24 for Wright Air Development Division. This instrument, delivered in 1958, became one of the country's first solid-state, digital computers for airborne use. Today, it is fully ruggedized and miniaturized, has a volume of only 0.55 cu. ft. and weighs 37 lbs., excluding input/output.

The need for "off-the-shelf" hardware with proven reliability led to the selection of Minneapolis-Honeywell and Librascope to provide the inertial platform and the computer for the total guidance package in Convair's *Centaur* space vehicle.

While this package has received wide publicity as the first digital computer to be employed in a space vehicle, other engineering groups within the division have been making approaches with no less notable achievements. One example has been the completion of a digital computer which had to be designed around the packaging criteria of a unique (and still highly classified) military missile configuration.

With an eye to tomorrow, the division is working on an expandable airborne computer and an approach to the computation requirements for strap-down inertial systems now in development.

A solid-state memory is under development for a guidance system applicable to an operational *Saturn*-type space vehicle. This unit is comprised of one-inch cubes of silicon wafers

**Mr. Williamson, now director of military sales for Librascope Division, General Precision, Inc., served previously as a staff engineer and later as director of advanced systems and planning in the company's aerospace branch. He has been a major contributor to digital computer design and development, and holds several patents in the field.*

with etched and vacuum-deposited components and circuitry. Storage capacity will be 70,000 bits per cubic inch.

In time, many believe, an all-solid-state inertial guidance system without any moving parts will evolve.

This is but a thumbnail sketch of just one company's work in this area. Librascope is not, of course, alone in its competence in this field.

• **Centaur will lead the way**—However, it does feel that the first use of the digital computer in the *Centaur* will carry with it the philosophy of design, demanded by the space application, that will be seen in the development of tomorrow's guidance computers.

It is a lightweight, miniaturized, general-purpose instrument, employing solid-state components and printed circuits. Of utmost importance during its development was the need for careful decisions on components, packaging and logical design to insure reliability.

The *Centaur* computer employs a drum memory, a proven device necessary for the rigors of space environment. Other devices will no doubt supplant the drum. But it still remains an effective answer to today's demands for economic utility and reliability.

• **Eleven urgent needs**—Reliability is the essence of space application. Each of the future needs in computer development is based on this requirement.

The reliability factor cannot be limited to the computer alone, nor can we afford to focus our attention on any particular component of the computer.

The approach must be taken from the systems viewpoint. It means little to have a computer function perfectly, if a sensing or control device fails.

Reliability starts with the analysis of our needs and problems, and in the concept we apply as a solution.

The key here is conceptual simplicity—simple in form but capable of solving problems.

This point, reliability, is the first of eleven requirements for the future.

The second is a reduction in reaction time. This would apply particularly to the military area. Needed is the elimination of pre-checking, prealignment, and the time-consuming preparation of a guidance device before launch. Here again we ask for simplicity. The approach here would be in design.

A third requirement is the reduction of power needs. The benefits would be in weight saving and, again, improved reliability by reduction in heat generation. (For example, in the *Centaur* application, Librascope provided the computer with the capability of turning itself off when not in use to meet the recognized need of lowering power requirements.)

A fourth point is the need for all-solid-state devices, not just computers, in space. This means, simply, no rotating parts that take energy to counteract. Again we find the benefit of higher reliability with the elimination of moving parts that can wear out.

Fifth, we should note that so far only digital computers have been mentioned. We face an added need for optimizing the use of analog and digital equipment in space systems to insure that we are making effective use of our resources in meeting the problem.

Redundancy is the sixth point. Effective use of this technique at many levels of our space systems will again enhance the reliability factor.

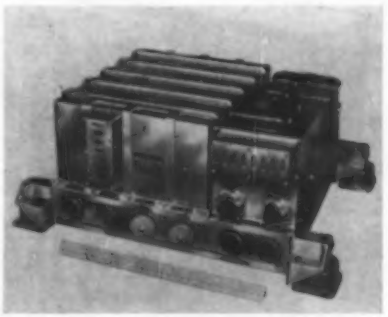
The seventh point has been touched on, but it bears repeating: The guidance approach toward the spacecraft problem is tending toward a combination of inertial-optical-angular position sensory equipment. This has been recognized, and many have long concentrated their efforts in the area of optical devices and sensing equipment.

The eighth requirement—a long-range consideration—is that molecular electronics will be phased into use for computers in space. But before this happens, we will see a reduction and improvement of interconnectors in present-day equipment. This will be a design approach and will provide an increase in reliability. Actually, the interconnector problem must be solved before the technique is perfected.

As point number nine, we should again stress the need for over-all system simplicity. This has to be approached on every front of the design problem. It might be beneficial, in the interest of reliability and simplicity, to consider the use of a number of simple computers in a spacecraft in lieu of a single multipurpose instrument.

Also (as the tenth requirement), we have the necessity of providing a means for easy maintenance of equipment. The man in space will depend on the support of computerized systems. If necessary, he must be given the means of quickly repairing any portion of the system and restoring its usefulness.

Lastly, I return to my opening statement. The digital computer will be the keystone of our space venture. Development progress will, of course, come about as a result of the broad growth of technical competence in this area. Nevertheless, as an essential building block for this program, it deserves a concerted and continuing effort by all concerned with this quest.

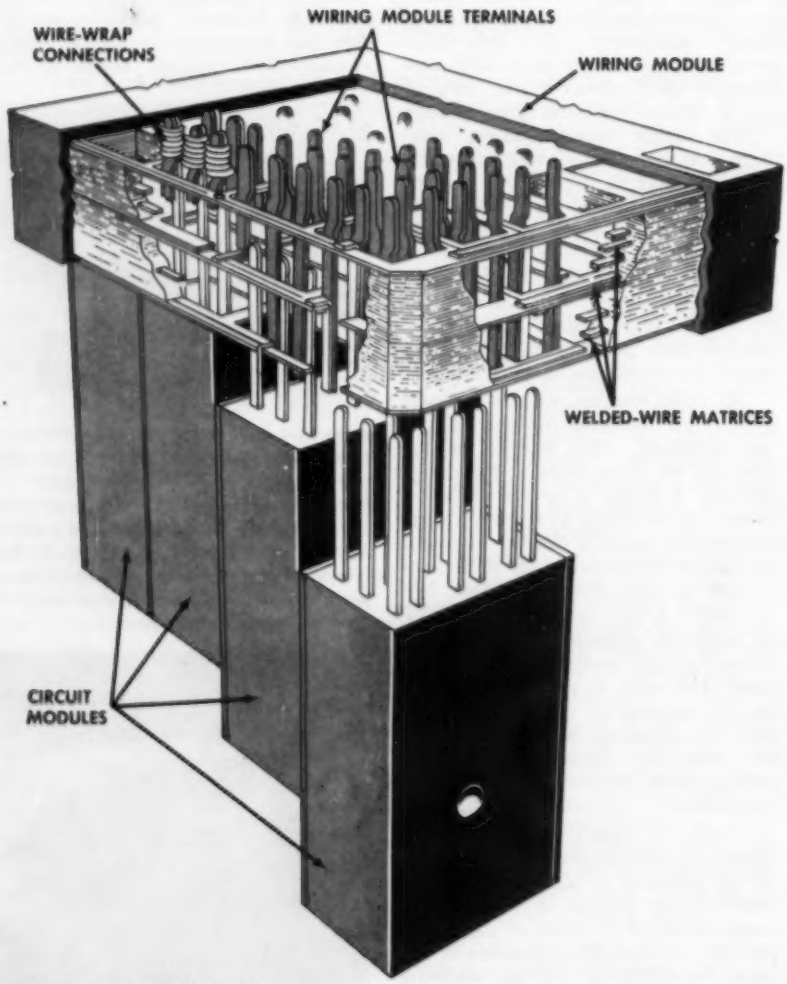


TOP: *Silicon permanent array memory, developed by Librascope, employs these discs as major components. Each is only 0.008-in. thick, 1 in. in diameter. Dots are diodes. Later production includes etching and diffusion to isolate diodes.* **MIDDLE:** *Centaur digital computer (left) and input-output equipment (right) produced by Librascope weighs 57 lbs. overall, is gold-plated to aid in temperature control. Magnetic memory provides total storage of 2560 words, each 25 bits long.* **BOTTOM:** *Miniature airborne drum assembly developed by IBM Federal Systems Div. laboratory weighs 8 lbs., compared with 235 lbs. for conventional drum assemblies. Slider bearings ride thin layer of air on drum's surface.*

Erector-Set Guidance Computers

'MiniWeld' technique invented by Francis Associates used to build systems for the Polaris, Minuteman, space vehicles; sales of nearly $1 million seen this year.

by Hal Gettings



DETAIL OF ASSEMBLY shows how circuit modules are interconnected by wiring module and wire-tapped terminals. The wiring module is made up of layered welded-wire matrices separated by insulating films.

TOMORROW'S GUIDANCE computers may well come from a Space-Age supermarket where the parts are bought off the shelf and put together like a combination egg-crate and erector-set.

The high-density standardized circuit packages and modular hardware for such electronic systems are already on the market. With the new technique, called "MiniWeld," complete systems may be made up with compatible digital circuit modules, intercircuit wiring modules and cabling, and mechanical and thermal building blocks. Up to 200 circuit modules—counters, storage units, delays, drivers, inverters, and logic blocks (NOR, NAND, pulse, and DC)—may be assembled into synchronous or asynchronous systems. Over 150 different digital circuit modules are available from the manufacturer.

This new system concept uses several unique techniques in the different components. Welded-wire circuitry is used exclusively in both circuit modules and interconnecting wiring modules. The Bell-developed wire-wrap method is used instead of conventional connectors to give inherently higher reliability.

The unique mechanical assembly of the completed system makes it essentially a solid block with high resistance to shock and vibration. Disassembly is simple, however, and units can be replaced in a minimum of time. Cooling can be incorporated in the package to meet any design demands.

The MiniWeld technique received the 1959 Miniaturization Award—the first ever given for a total system concept. The technique was invented by Francis Associates and developed by Sippican Corp. Electronic Engineering Co. of California did systems R&D; their affiliate, Engineered Electronics, builds and sells the packaged circuits and mechanical components.

Versions of the MiniWeld system are being built for use in *Polaris*, *Minuteman*, and various space vehicle programs. Almost $1 million worth of the equipment is expected to be sold in 1961.

The Mini-Circuit module is the basic unit in a MiniWeld system. These modules are assembled parallel to each

other in an erector-set frame—similar to the way eggs are crated—and held together in compression about a central plate. The minimum frame holds a stack of 10 modules, the maximum 200. When more than 200 of the modules are required in a system, the frames may be stacked together. Where needed, "cold-plate" building blocks, which provide cooling ducts, are assembled adjacent to the circuit modules.

Interconnections between the various modules are made by means of a wiring module which fits on top of the frame. Circuit terminals project through the wiring module and match up with interconnection terminals. These pairs are then connected by wire-wrapping. Cable modules—made of flexible printed wiring and potted terminations—carry signals and power between frames and to front-panel devices and accessory assemblies.

The complete frames, with their wiring modules and interconnecting cables, are stacked on a cooling-fan assembly and bolted to the holding structure. Clamping bolts, inserted through each row of modules and pads at each end, hold the modules together to form, in effect, a homogeneous whole.

• **Mini-Circuit Modules**—The welded-wire matrix (M/R, Oct. 10, 1960) is the basis of construction of the individual circuit modules.

The module components are stacked with their bodies in physical contact and their leads parallel—in a "cordwood" technique. Components which vary in size or shape are arranged to fill the least possible space, taking into account their thermal and electrical characteristics. High-power dissipating components, for instance, are given special consideration in the component layout.

Mylar films, with the cross-sectional dimension of each component drawn in full scale, are used to arrange the components in proper order during fabrication. Dots on these positioning films indicate where holes must be punched to accept the component leads.

Connections between components and to Mini-Circuit terminals are made by the welded-wire matrix. Resistance-spot-welded connections are used because of their inherent reliability, volumetric efficiency, and elimination of thermal damage to sensitive components during assembly.

The matrices consist of two layers of wires at right angles to each other, separated by a Mylar film. Welds may be made through holes in the Mylar to make connections between the perpendicular matrix wires, or from a

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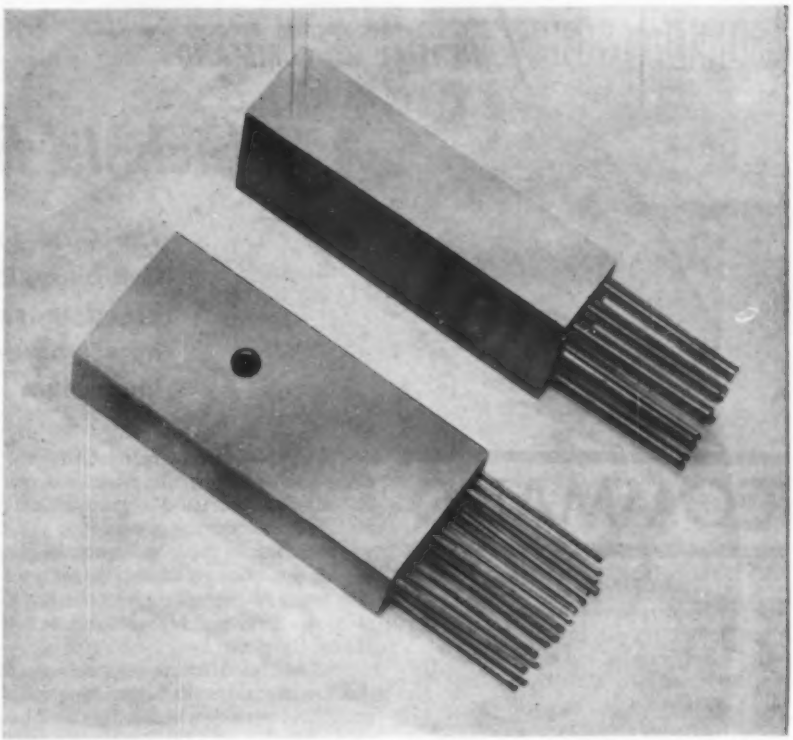
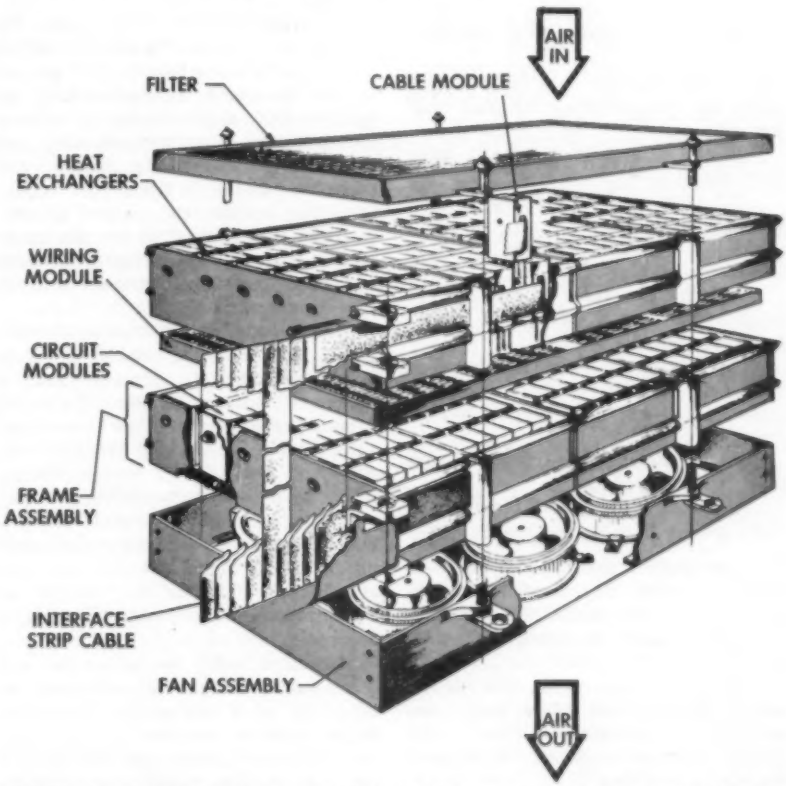


CIRCUIT MODULES are made of welded-wire matrices which hold and connect the various components. Connector terminals are welded to the matrix pins, and the entire assembly is encapsulated in an epoxy resin.



MODULAR COMPONENTS of the MiniWeld system are stacked and bolted together to form a compact and rugged package. The cooling unit, if needed, is an integral part of the total system. Minimum external wiring is required.

Which Is Best Approach

COMMAND

The Case for Radio Command: Accuracy, flexibility, low weight and small size combined in system which can be produced now; hardening is possible, jamming impossible

by L. J. France and
R. C. Litty*

THE TECHNIQUE of guiding a missile by a radio command link from the ground results in the most accurate, most flexible, and the smallest and lightest guidance system available today. Advanced radio-guidance techniques provide phenomenal accuracies —and they are ready for immediate hardware implementation.

Certain primary advantages attributed to inertial guidance have been instrumental in establishing its present status. These include four impelling virtues:

(1) Its accuracy has become adequate for area targets with high-yield weapons.

(2) Its launch sites can be hardened easily.

(3) It is invulnerable to electronic countermeasures.

(4) It inherently permits simplified simultaneous launchings.

Nevertheless, these points can be countered by the advantages of today's radio guidance:

(1) Accuracy. Radio guidance is sufficiently accurate for hardened point targets using relatively low-yield weapons.

(2) Hardening. Radio guidance sites now can be hardened.

(3) Countermeasures. Jamming of radio guidance is impractical.

(4) Multiple launching. Advanced radio-guidance systems possess a traffic handling capacity significantly higher than earlier systems.

In addition, radio guidance has the advantages of more flexible target selection (even to changing targets in flight), mission recall, and higher airborne reliability.

• **Look at Mistram**—In defense of this argument, we shall describe a radio-command system which offers still better performance in these important areas, and at the same time compares favorably in those areas where inertial systems previously enjoyed certain advantages.

A radio-guidance system typically consists of a ground guidance station and a missile borne beacon. The ground station is capable of determining the position and velocity vector of the missile, and then computing, encoding and transmitting commands which will place the missile in the proper trajectory. The beacon receives and retransmits the signals required for the tracking function and also receives, decodes and acts upon the commands sent by the ground station.

Radio systems, using new techniques, can track the path of a missile with extraordinary accuracy. Such a system is Mistram (*MIS*sile *TRA*jectory *M*easurement System) now under development at the General Electric Company for the Atlantic Missile Range. This missile instrumentation system, which is scheduled to provide the primary range safety and instrumentation on all missile flights out of Cape Canaveral, will illustrate the manner in which radio systems could achieve these accuracies.

Mistram makes use of an old and often-used technique to determine the trajectory of a test missile. The technique involves the use of an interferometer, and utilizes the fact that the point in space at which a signal originates may be determined by simultaneously measuring the relative phase of the signal at three known points.

Mistram differs from previous applications in its ability to perform these measurements accurately over very long baselines (separation between the three known points). This, combined with novel ambiguity resolving and ranging schemes, accounts for its unusual capability.

The basic Mistram ground station consists of three sites arranged in an "L" configuration. The central station houses both a transmitter and a receiver; the outlying stations have receivers only.

The central station transmits two continuous wave signals at different frequencies to the missile. Since these signals are derived from a common source, they have known and controlled phase relationships.

The airborne beacon receives the two signals from the ground, and transmits to the ground two return signals whose phase relationships are controlled with respect to the received signals. Because of this control, both the phase and frequency of the airborne transmitted signals are a direct function of the ground signals, the distance to the ground station, and the velocity vector of the missile.

At the ground sites, the signals from the airborne equipment are received and used to make the interferometer phase comparisons. Doppler measurements also are made on one signal at each of the three receivers to determine the velocity of the missile. To keep the errors low, the electrical lengths of the base lines are measured and the phase data continuously and automatically corrected.

To measure range with this system, a continuous count could be kept on the cycles of Doppler shift from launch, using one of the above signals. While this method can be in error if there is

(Continued on page 65)

**Mr. France is a project engineer over advanced transponder development for General Electric's Light Military Electronics Department, Utica, N.Y.*

Earlier, he was responsible for the entire ground-based radar and communication jamming program for USAF projects at Rome, N.Y.—Air Development Center.

Mr. Litty, also at GE's LMED, Utica, is a project engineer in Doppler products engineering.

The views of these articles are those of the authors, not necessarily those of the Department of Defense.

ccurate Guidance of ICBM's?

The Case for Inertial Guidance: Complete self-containment cuts ground installation costs, enhances mobility, provides salvo capability—and guidance during re-entry

by R. E. Wilson*

INERTIAL

INERTIAL GUIDANCE has long been attractive from the military point of view, because it is completely self-contained, passive, and nonjammable.

In the past, radio guidance has been favored, largely because of the accuracies which it made possible. However, in the near future, accuracies believed obtainable with inertial guidance will make this the favored approach.

Most of the desirable characteristics which can be claimed for inertial guidance stem from this fact: the system is completely self-contained, and with minimum use of external aids can erect, align, calibrate, and check itself out prior to flight.

Several advantages result. The need for costly ground-based guidance installations, either fixed or mobile, is eliminated. Missiles can be set up and launched rapidly from mobile sites. The number and dispersion of missiles at fixed or mobile sites are limited only by the ability to feed in the desired command requirements. By the very nature of inertially guided missiles, salvo capability is provided.

Attitude reference information is provided during the entire flight. This can be used to simplify the control system during the powered phase to orient the missile for re-entry, and to stabilize during re-entry. Thus, complete re-entry guidance can be provided for maximum-accuracy missiles.

Inertial guidance provides longer positive control capability for maneuvering ICBM's. By storing alternative courses of action in the airborne computer, simple coded radio commands can be used to select any of several targets. Similarly, evasive maneuvers also can be programed.

The inertial guidance system may well provide a reliability advantage when it is considered that each missile is completely self-contained.

Another advantage — price — will become apparent in the future. Complexity and cost of ground-based equipment required by other guidance methods continue to rise. Conversely, the inherent simplicity of inertial guidance eventually will make it the most economical method.

Such present and potential advantages as these have led the military services to invest considerable funds in developing inertial guidance systems. These developments have taken place despite the fact that no less than a dozen years ago most experts asserted that the accuracies which are obtained regularly today were impractical. The accuracies which will be obtained in the future would then have been considered impossible.

The basic sensors of any inertial guidance system are the accelerometers for measuring the three components of acceleration and gyros for measuring the three angular directions. In addition, a missile computer is used for integrating and resolving the acceleration information to determine the instantaneous velocity of the missile. This is compared with a computed desired velocity. The computer then issues the desired control commands.

Let's examine some of the factors which influence the decision as to whether radio or inertial guidance should be employed.

• **Accuracy**—Theoretical studies indicate that both present and future all-inertial guidance systems are not yet approaching the theoretically obtainable accuracy.

**Mr. Wilson is a consulting engineer for inertial navigation systems in the Armament & Control Section of General Electric's Light Military Electronics Department, Utica, N.Y. He has been responsible for, or served as a consultant on, a wide variety of control and inertial system projects for submarine, aircraft, land vehicle, missile, satellite, and spacecraft applications.*

Inertial guidance at present is limited primarily by the quality of existing gyros and accelerometers. However, a number of new inertial sensors in development show promise of accuracies so much improved that practically pickle-barrel ICBM guidance may be possible.

The major error sources will then be in parameters which are common to both radio and all-inertial guidance systems—location of targets and knowledge of the physical constants of the earth.

The all-inertial guidance system has a major theoretical advantage over radio guidance—its ability to provide re-entry guidance. This could be a major factor, and unless fairly complicated terminal guidance equipment is used to provide target detection capability, the most accurate guidance systems of the future will be all-inertial. If this terminal guidance equipment is used, the accuracies will not be particularly critical for either system.

• **Reliability**—At present, considerable development effort is being expended to increase the reliability of all-inertial systems. The present trend is to reduce the complexity of the inertial sensors and the electromechanical elements and to put more of the guidance task into the missile digital computer.

The tremendous advances in designing small, ultra-reliable digital computers in time will make inertial guidance systems so reliable that this will no longer be a major factor in selecting guidance-system type.

• **Initial erection, alignment and response time**—Inertial systems require significant development effort in order to provide rapid, accurate initial erection and alignment under all tactical situations.

Also involved in the response time is the major problem of warm-up of the components. This can be solved by continual operation of the inertial guidance system, and the initial erection and alignment response time can be reduced

(Continued on page 68)

ARMA Cuts Weight, Adds Reliability

Experience with inertial system for ICBM produces guidance which company sees as answer for both long- and short-duration missions

by Stan Shatunoff*

THE ARMA DIVISION of the American Bosch Arma Corporation is developing an advanced inertial system which promises to satisfy the future navigation and guidance requirements of airborne terrestrial and space missions.

Two years in development, this outgrowth of the *Atlas* ICBM all-inertial guidance system offers significantly lower weight and higher reliability. It is expected to be more accurate in both ballistic-type, short-period guidance missions and long-endurance, cruise or glide vehicle-type missions.

Recognizing that flight of the future will merge the requirements of ballistic missile environment with those of conventional cruise-type navigation, ARMA has heavily emphasized development of miniature gyros, accelerometers, and a flexible, all-transistorized digital computer. The latter will provide the performance demanded of a system that successfully guides a vehicle during boost, through injection, through mid-course orbital or glide flight and into touchdown.

Heart of the system is the four-gimbal inertial platform. The completely integrated platform includes its own electronics—average power required is less than 235 watts.

In terms of mechanical and electrical design, the platform reflects refined concepts evolved from the advanced *Atlas* product improvement program.

• **Single inner bearing**—Nucleus of the platform is an inner azimuth gimbal mounted on a single equatorial bearing. This feature saves space while providing rigidity and maximum accessibility to major components, for easy assembly test and maintenance.

Mounted orthogonally on the azimuth gimbal are three vibrating-string accelerometers—advanced miniaturized versions of the configuration in *Atlas*—and two two-degree-of-freedom gyros which stabilize the platform through the servo-driven isolation gimbals. The two gyro housings and the three accelerometers are rigidly attached to the azimuth gimbal or stable table.

Gimbal servo amplifiers, accelerometer oscillator-amplifiers and gimbal pickoff pre-amps are gimbal-mounted for maximum utilization of space. This technique minimizes slip-ring sizes, as well as external connector sizes and interconnecting cabling.

Other units—such as the proportional temperature control amplifier, power supply, and modes control devices—are in an Electronics Unit mounted on the platform housing.

The gimbal system is made up of azimuth, inner-roll, pitch, and outer-roll gimbals which provide all-attitude angular freedom for the platform. The four isolation gimbals are positioned by slaving each gimbal servo to an appropriate angular pick-off.

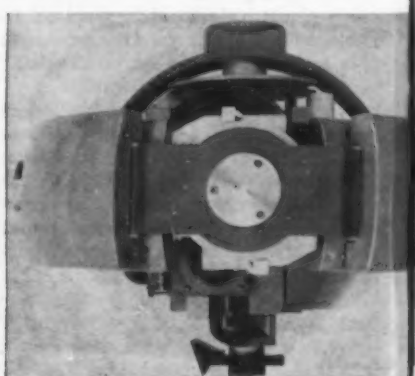
The gimbal servos employ two-phase, 400-cycle induction-type motors specially designed for high-performance, high-temperature operation. Two motors are used on each axis, mounted in a push-pull geared type arrangement.

The selection of this type of geared AC motor rather than a DC torquer is based upon tests and experience encountered in the *Atlas* guidance development program. Incremental digital pickoffs are used to measure rotation of each of the platform's isolation gimbals. These data are utilized during the system's ground calibration and alignment phase, in addition to providing the guidance system with vehicular attitude data.

Thermal control of the inertial platform is achieved by means of a proportional temperature control system consisting of:

–A temperature sensor, a platinum

*Technical Staff, ARMA Division, American Bosch Arma Corp., Garden City, Long Island, N.Y.



Outgrowth of Atlas Work

Mockup of inertial platform developed by ARMA. Other cutaway views indicate unique, compact construction resulting in 75% reduction in size.

sensing element in a precision bridge circuit.

–A temperature control amplifier, a solid-state device which provides control of heater power between 0 and 80 watts.

–Strip heaters suitably deployed to minimize temperature gradients and hot spots.

–Three fans directing the flow of air through the platform.

The two-degree-of-freedom floated gyro (ARMA type G-8) used to stabilize the platform is another design refinement of the gyro already in production for the present *Atlas* system.

Under development since 1957, the new gyro has been extensively evaluated for over 1½ years in vibration and long-term stability tests. Extensive systems and error analyses of boost-glide orbital missions, recoverable orbital reconnaissance missions, 24-hour orbital missions and long-endurance high-speed terrestrial flights have shown that the gyro meets all the reliability, performance and environmental requirements of these tasks.

The accompanying cutaway drawing shows the two floated gimbals used in the gyro. The inner gimbal is a hermetically sealed beryllium sphere which contains the spinning wheel supported on precision ball bearings. The outer gimbal is a beryllium ring surrounding, but not touching, the inner gimbal.

Two degrees of freedom are supplied by thin-elastic centering filaments. One set of filaments connects the floated sphere with the gimbal ring and the other connects the gimbal ring with the outer housing.

Pickoffs detect rotation of the gyro housing relative to the inner gimbal, and torquers process the gyro about each of the two stabilization axes during tests and initial system alignment.

• **Vibrating string accelerometers**—The key component of the platform—the accelerometer—also has been under development for over two years. Although functionally identical to the vibrating-string accelerometer in *Atlas*, the new D-4 is considerably smaller in size and weight, less sensitive to transient and steady-state temperature changes and considerably reduced in its non-linear characteristics. This miniaturized accelerometer represents the knowledge and experience gained during five years of design and production of hundreds of vibrating-string accelerometers.

The measurement of acceleration is accomplished by measuring the reaction to an acceleration force acting on a constrained weight (proof mass). The proof mass is supported within the accelerometer by longitudinal strings and transverse cross supports.

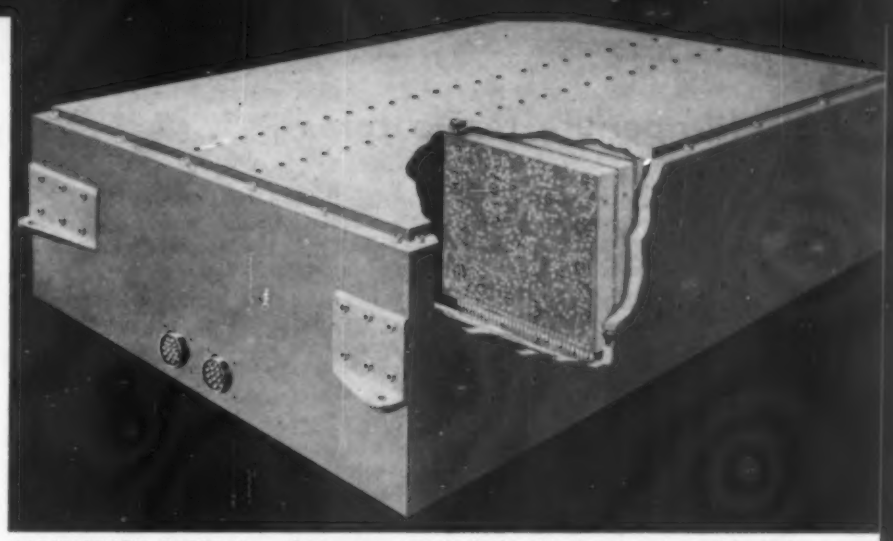
The cross supports prevent motion in a plane perpendicular to the sensitive axis. The component of acceleration force along the sensitive axis changes the tension of the longitudinal vibrating strings: one string increasing in tension and the other decreasing. These changes in tension are measured by noting the changes in the resonant frequency of the vibrating strings.

The all-transistorized electronics portion of the accelerometer system consists of an oscillator-amplifier package utilizing high-density packaging techniques. This package, containing six identical oscillator-amplifiers and a power supply, is mounted on the azimuth gimbal of the stable platform.

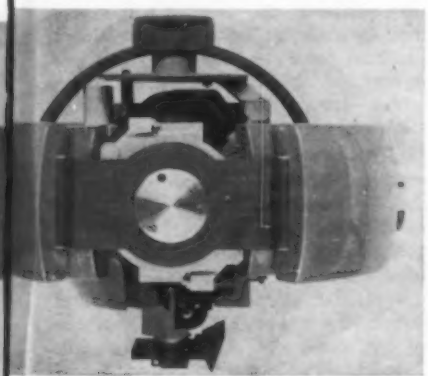
The D-4 accelerometer is designed to operate accurately in the presence of input accelerations up to 20 g and is insensitive to cross-acceleration. ARMA believes its long life and high reliability—due mainly to the complete absence of moving parts, coupled with its exceptionally good long-term stability characteristics—make it an ideal instrument for all future inertial guidance requirements.

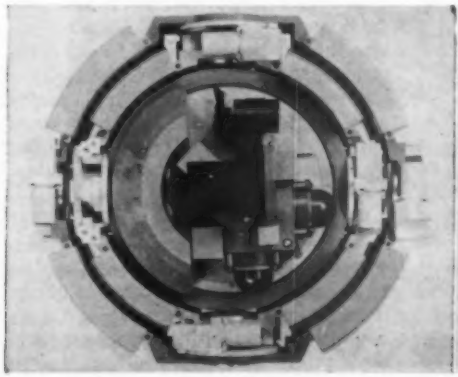
• **Solid-state computer**—The brain of the ARMA advanced inertial system is a lightweight, flexible, all-transistorized digital computer which has no moving parts and incorporates in its design the most advanced fabrication techniques.

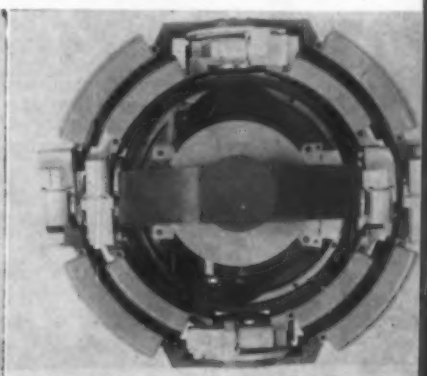
The role of the computer is to accept data from the three platform-mounted accelerometers and the digital pickoffs on the gimbals, and to process this data to yield navigation information and guidance steering orders.



SOLID-STATE DIGITAL guidance computer is built with honeycomb or labyrinth type of construction to keep size and weight at a minimum.







multi-aperture ferrite cores . . .

Since future requirements call for flexibility of computer programing and constants storage, a development program was initiated to evaluate the utility of multi-aperture ferrite cores as the primary computer storage medium. The program has shown that many of the disadvantages heretofore associated with multi-aperture core devices may be avoided by using a "coincident-flux" technique rather than the "coincident current" method usually recommended.

A distinct advantage accrues from employment of the coincident-flux technique, because the cores may be operated over a wide temperature range with very little current-amplitude temperature control.

• **Storage**—The memory unit of the flexible computer consists of 2048 words of program storage and 128 words of working storage.

The program and constants memory is composed of 32 multi-aperture ferrite core planes of 32 rows each. The planes are word-organized with two 16-bit words in each row. Constants, which are 28 bits long, occupy two words in this memory. Read-out from the memory is performed in parallel into the program memory output register.

Constants are read out in two groups, of 16 and 12 bits, respectively, with serial shift out from the output register. A parity check is performed on these constants before they are used in the program.

Address selection in the memory is carried out by the decoding matrix associated with an 11-bit program counter. Five bits specify a plane, five bits a row within that plane and one bit denotes which of the two words within that row is desired.

The working storage consists of four multi-aperture core planes of 32 rows each, with 28 bits per row and an 8-bit shift register. An address in this memory is determined by the information stored in the operand address register, with 2 bits designating a plane and 5 bits designating a row within the plane.

To read information into the working memory, the proper location is addressed and the information to be posted is read into the shift register. It is then written into the memory 8 bits at a time. Similarly, readout from the working storage proceeds 8 bits at a time into the same shift register with serial shift out from the latter.

Other units comprising the computer are:

–Control Unit. It decodes the instruction word, generates computer clock pulses, and controls the transfer of information between units.

–Arithmetic Unit. A separate multiplier-divider allows for simultaneous use of the accumulator for subtraction and addition while the slower operation of multiplication or division is being performed.

–Input Unit. An autonomous input unit collects accelerometer, gimbal angle data, and other information for use by the computer at programed intervals.

–Output Unit. Digital displays and digital-to-an-analog conversion is performed in this unit.

The Control Unit contains switching and logic circuits for the generation of special conditional gates, the control section for the transfer of information to and from the Arithmetic Unit Accumulator, and the necessary logic for the direct transfer of information to the multiplier-divider, and from the product output to and from working storage. The Control Unit contains the timing generator, the program Memory Output Register and the program counter.

The Arithmetic Unit can perform 1000 multiplications or 275 divisions in one second, simultaneously with 8000 addition or subtractions. It consists of an adder, a multiplier-divider, a sign determination circuit, an accumulator register (independent of the multiplier-divider) and a 2's complementing circuit.

The Accumulator includes a full adder, a magnetostrictive delay line register, and logic to control the operations of addition, subtraction, absolute value, logical "and," shift left, and shift right. For subtraction and absolute value operations, the 2's complement notation is used.

The Input Units can accept accelerometer data, roll, pitch and yaw data, and program and launch condition information provided from an external tape unit. The Output Units provide continuous data in both analog and digital form, in addition to a variety of discrete signals such as engine cutoff, malfunction indication, etc.

In this computer, the word—or basic unit of information—may represent numerical data or a computer instruction. Numbers are stored in binary fixed point, fractional notation. A 2's complement is used to represent negative numbers. Numerical data in the working storage consist of 27 magnitude bits and a sign bit.

The binary point is normally considered to be the left of bit position 1, i.e., all numbers are less than unit. However, as in all fixed point computers, the programer may, by proper sealing, place the decimal point anywhere in the number.

Instruction words are 16 bits in length, and are of a single address type. The operation portion of the word contains the binary representation of the command to be executed: e.g., add, subtract, multiply.

The operand address contains the address, in binary notation, of the memory location where the numerical data to be operated upon is stored. It may also represent the number of bits involved in a shift command.

There are 25 commands which can be executed by the flexible computer, and each command normally requires a fixed number of word times. (There are 8000 word times per second.) However, the execution time of certain commands may be extended up to 7 word times by storing the desired delay time as part of the command word.

Within the computer are 38 subassemblies, the transfluxor memory and several power supply components. All necessary external cable connections are available at the front of the computer.

• **Weight down**—Minimum weight is obtained, without sacrificing reliability, by a packaging technique in which the individual subassemblies are first designed to contain a minimum of support structure, and then integrated into a unified package. This generates a rigid high-natural-frequency honeycomb or labyrinth type of construction.

Lightweight materials are used which, for the given application, are outstanding in their strength-vs.-weight, or stiffness-vs.-weight properties. Extensive use is made of plastics, foams and magnesium extrusions.

The computer can be readily produced in large quantities with a minimum of skilled personnel. To achieve this objective, the computer has been modularized to as many similar or identical pieces as possible. These subassemblies or modules are, in themselves, simple to fabricate and lend themselves to assembly line techniques.

The optimum size of module to be used has been considered by studying the "trade-off" on module size, number of different modules, total number of components to do a particular task, total number of solder connections required, and necessary quantity of interconnecting cabling. Eight-five percent of the computer circuitry is complemented from 10 standardized modules.#

Titan II All-inertial System to be Tested Soon

FINAL CLEANING of a small gyro float used in Titan II inertial platform is performed in a lint- and dirt-free pressurized cabinet at AC Spark Plug.

by Dr. Joseph Shea

Titan II Guidance Project Manager, AC Spark Plug Division, General Motors Corp., Milwaukee.

TITAN II's highly advanced all-inertial guidance system will be test-flown before summer, 1961.

Initiated in 1959, when the contract was awarded to AC Spark Plug Div. of General Motors by The Martin Co., the system has been developed in a remarkably short period of time.

It had to be, for *Titan II* is scheduled to be operational by early 1963.

• **Inertial systems mature**—Design problems in the guidance of ballistic missiles have ceased to be a question of accuracy alone; they now focus on the operational advantages of one system over another. In the early days of the U.S. ballistic missile program, when guidance accuracy was considered the limiting factor in weapon system effectiveness.

In retrospect, the problem has not been as difficult as first estimated. The electronic industry has responded in each development undertaken with a system which meets all of the accuracy requirements of operational ICBM's.

In 1955 the advanced state of radio technique—monopulse, Doppler, interferometer—led to extensive development programs in these areas to satisfy the guidance requirements of our first operational squadrons. Inertial systems, attractive as they were operationally, had barely come out of the laboratory and were not considered good developmental risks.

The strides made during the last five years in the inertial field have been stupendous. Paced by the development of the inertial system for the intermediate-range *Thor*, which demonstrated both the practicability of inertial guidance for ballistic missiles and the producibility of the equipment, most operational U.S. ICBM's soon will be committed to inertial techniques.

One of the major programs is the development by AC Spark of the inertial guidance equipment for the *Titan II* vehicle.

• **Descendent of Skipper**—The *Titan II* guidance system is a second-generation inertial system. The instruments used are more than adequate to assure accuracy.

Major emphasis in the system design has been operational utility, simplicity, reliability, and maintainability. In addition to the normal operational advantages of inertial equipment, the system will provide essentially an instantaneous reaction time, plus automatic installation, checkout and malfunction detection.

The system will be maintained continually, kept in a state of readiness, with continuous evaluation of both gyros and accelerometers. Recalibration of the instrument to maintain specified performance can be done automatically. The black-box concept of maintenance provides easy replacement and repair with minimum operational personnel.

In addition to providing the guidance function, the missileborne system will be used as attitude reference for the vehicle, thereby incorporating the conventional autopilot function into the guidance system. The missile will be under positive guidance control from launch to cut-off.

Both the instruments and the inertial package are outgrowths of the "Skipper" program conducted at MIT under Air Force sponsorship. The effective working relationship between MIT and AC Spark has enabled the Skipper platform to evolve into an operational ICBM guidance system in a remarkably short time.

Although many details of the *Titan II* guidance system and its accuracy are classified, a general description of the equipment can be provided.

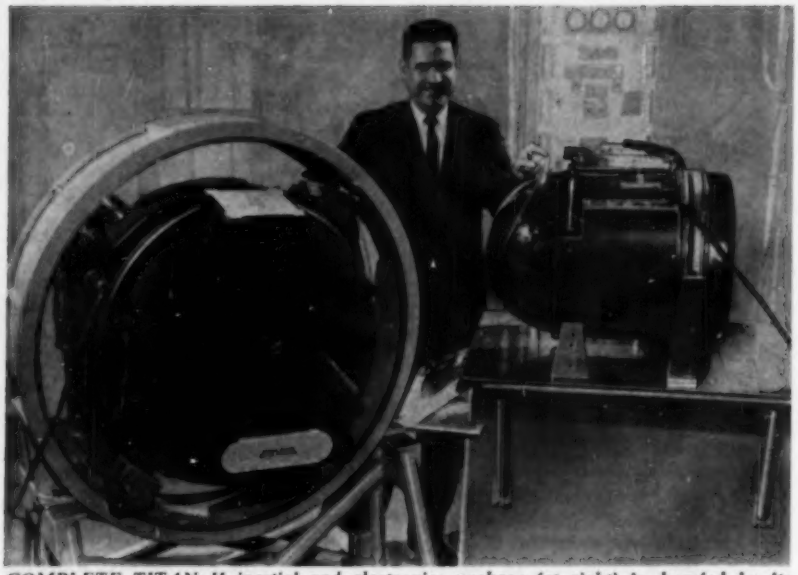
To meet weapon system requirements for the *Titan II* missile, an inertial guidance system was required.

Among the advantages that an all-inertial guidance system presents to the weapon system are fast reaction time, minimum ground operating equipment, invulnerability to jamming devices and the capability of salvo launch.

The requirements placed upon the guidance system by the weapon system requirements include high reliability, automatic malfunction detection and semiautomatic malfunction isolation, maximum ease of replacement and repair with minimum operational personnel, operation from a hardened silo, and, of course, pin-point accuracy.

• **Platform and electronics**—Two pieces of inertial guidance equipment will be mounted in the bird: the inertial measurement unit (IMU) and the missile guidance computer (MGC). Heart of the guidance system is the stabilized platform contained inside the gimbals of the IMU. The platform is slaved to an earth-fixed set of axes prior to launch, but maintains an inertially fixed orientation during flight.

The platform mounts stabilization



COMPLETE TITAN II inertial and electronics package (at right) is dwarfed by its predecessor, the Thor IRBM guidance platform, shown here without its pallette of associated equipment. Dr. Joseph Shea, author of the accompanying article, directed the Titan II project for AC Spark Plug Division.

gyros, integrating accelerometers, a vertical sensing element, a porro prism and a fluid temperature control system. The 2FBG (floated, single-degree-of-freedom, beryllium) gyros and the PIGA (Pendulous Integrating Gyro) accelerometers manufactured by AC are used in the platform basic design developed by Massachusetts Institute of Technology. These units—of conventional, conservative design—have demonstrated performance necessary to assure high accuracy.

The stabilization gyros are used to sense angular motion, and, through its associated servo loops, control the gimbals to maintain the platform in its stable position. The accelerometers sense any linear acceleration, convert this into velocity increments and put out digital velocity information to the missile guidance computer. The digital outputs emanate from a transducer incorporated within the accelerometer.

The vertical sensing element, commonly called a pendulum, is used as a vertical reference for the erection of the platform. The porro prism is employed to reflect a beam of light back to an electro-theodolite set to establish the azimuth reference during erection.

Key to performance of an inertial system is temperature control. In order to improve control of both absolute temperatures and the gradients through the instruments and platform, a fluid is circulated through the accelerometers, gyros and platform.

The fluid temperature is controlled to a fraction of a degree in a central heat exchanger. This system provides a degree of control unattainable in systems using air.

In addition to measuring missile motion, the platform is used as an attitude reference for the vehicle, thereby eliminating the conventional autopilot reference package. A transducer mounted on each gimbal axis furnishes digital missile-attitude information to the computer.

This entire gimbal package is combined with a cylindrical electronics package which contains the power supplies and servo amplifiers to operate the stabilization and accelerometer servo loops. The electronics package is mounted on a heat sink and air conditioning is supplied to the IMU during ground operation.

The electronics packages are manufactured utilizing the welded encapsulated module (WEM) technique. All electrical connections are welded rather than soldered to meet high reliability requirements.

The entire IMU weighs less than 200 pounds.

• **Computer controlled**—The digital outputs from the accelerometers and gimbal angle transducers are the inputs to the missile guidance computer. The computer is a serial, binary, whole word, programable machine manufactured by the Federal Division of International Business Machines Corporation. A magnetic drum is utilized for both permanent and temporary storage.

The computer combines the transducer data with pre-stored target and IMU characteristics data to supply outputs to the missile control system. These outputs consist of the steering signals for roll, pitch and yaw control and a series of discrete signals commanding engine cutoff operations. The programing function is also handled by the computer.

The drum is mounted in the center of the computer and is surrounded by panels containing the digital circuitry. This circuitry, too, is welded and is packaged in "logic sticks."

• **Alinement and checkout**—Guidance alinement and checkout console and an electro-theodolite set comprise the directly associated ground support equipment. The console is a four-bay unit containing all the equipment required to furnish power, erect, and maintain the missileborne equipment in its readiness condition.

It provides comparators necessary for automatic fault detection, and the logic required to isolate the fault to a replaceable panel. The console also mounts the punched-paper tape equipment necessary for loading target information into the computer.

Test capability is included to periodically exercise the entire system for preventive maintenance purposes.

The electro-theodolite set is mounted in the silo wall so that it has a direct line of sight to the porro prism on the inertial platform. It contains a reference porro which is used as a transfer device to a first-order reference established at ground level.

The error signal generated by the theodolites is used by the erection servos to align the platform and maintain it at an exact aximuth.

The system is interconnected with the launch control center so that the launch control officer remotely can control and monitor the guidance system. The system is designed to monitor itself automatically for readiness capability during normal operation. The alinement and checkout console and the missileborne computer combine to furnish this capability.

If an accelerometer scale factor should change by a specified amount, or if gyro torquing current should vary, the system will detect the change and recalculate the required compensation. The new compensation will then be stored in the computer without operator handling.

At lift-off, the guidance system—stabilized in inertial space—proceeds to steer the missile through staging to final engine cut-off in such a way that the payload will follow its ballistic trajectory to eventual impact at the target.

Evaluation of the *Titan II* inertial guidance system consists of a series of in-plant operational and environmental tests, as well as field test programs on the rocket-sled track at Holloman AFB, N.M., at Cape Canaveral, and at the Pacific Missile Range. ⌗

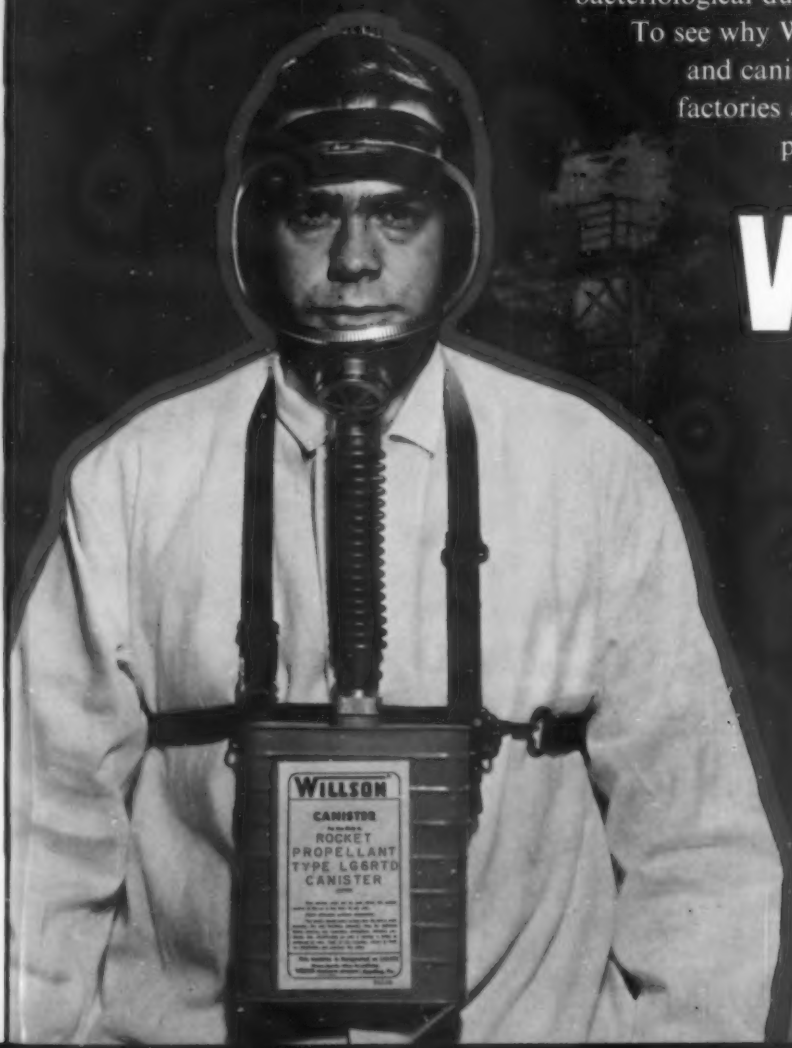
Willson first with respiratory protection against rocket propellants

Now, people working with exotic space age chemicals have fully portable emergency protection against dangerous vapors and gases. Willson rocket propellant gas mask and canister meet M21 specifications of the Protective Development Division, U. S. Army Chemical Research and Development Laboratories, Maryland. These Willson protectors neutralize toxic acid, organic and ammonia-type liquid propellants: red fuming nitric acid (RFNA), unsymmetrical dimethyl hydrazine (UDMH), hydrazine, hydrogen peroxide, kerosene, aniline, alcohol, and splashes from liquid nitrogen tetroxide.

Also available: military-type Willson rocket propellant canister with prefilter for radioactive and bacteriological dusts and smokes.

TITAN, ICBM, MARTIN COMPANY

To see why Willson rocket propellant gas masks and canisters already are in use in leading factories and military installations everywhere, please turn the page.



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SAFETY IS WORTH WORKING FOR
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Willson rocket propellant canister carried on back (top photo) allows more freedom in confined space. Keeps canister away from heaviest gas concentration. Rubber half mask (bottom photo) covers nose and mouth air-tight for escape protection. Pleated nosepiece, soft rolled edges, and chin cup fit any face comfortably. Threaded connector on all canisters.

Willson rocket propellant protection for more people at less cost

Because of economical pricing, Willson rocket propellant gas masks and canisters can be used to protect more people over a wider area. The same dollar expenditure will provide escape protection for four times as many people as can be equipped with expensive self-contained breathing apparatus.

Control eager "hypergolic" propellants (fuel and oxidizer combinations which ignite instantly when mixed).

Willson offers this exclusive line of protection against rocket propellant hazards:

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Special military M15-type canister with prefilter for radioactive and bacteriological dusts and mists.

Front-carrying harness or back harness for canister.

Gas mask with half facepiece.

Gas mask with standard Willson facepiece and six-strap head harness adjustment.

Gas mask with full-face Scottoramic window and Willson Tite-Seal® headgear.

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Exclusive Willson Tite-Seal® headgear for full facepiece rocket propellant gas mask permits easy, immediate airtight adjustment. With Tite-Seal® headgear two ratchet adjustments can be preset for a permanently adjusted fit. Immediately useful in any emergency. Headgear molded of low-moisture-content nylon—lightweight, easy to clean, unaffected by temperature extremes, fits under safety hats or caps . . . *AND* it is Bureau of Mines-approved.

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GUIDANCE / *MINUTEMAN*

PRODUCTION WORKERS at Autonetics at work on detailed wiring for Minuteman's solid-state digital guidance computer. Note relative size of cylindrical unit. Computer guides bird, checks calibration and alinement during storage.

Minuteman System Is 'Most Reliable'

Long stand-by requirement imposes special demands not applied to other ICBM's; Feb. 1 firing demonstrated accuracy

by Rolf Winterfelt*

EXTREME ACCURACY, high reliability and storability, and relatively low cost are the primary design characteristics of the Air Force's new *Minuteman* ICBM guidance system.

The inertial guidance system for *Minuteman* has to be reliable beyond the state of the art of other such systems. Such a severe design requirement was mandatory because the missile must be capable of dependable operation after long stand-by periods.

It has been only a short time since the first production-type inertial guidance system for *Minuteman* was accepted by the Air Force from Autonetics Division of North American Aviation, Inc., associate prime contractor for the missile's guidance and flight control. On Feb. 1, 1961, this completely integrated system was in control of the first *Minuteman* flight, —a 4200-mile trip down the Atlantic Missile Range and reportedly well within the target area.

Since then, even more advanced *Minuteman* guidance systems have been delivered and integrated into the missile.

Development of inertial instruments has progressed to the point where they can now provide precise information for calculation of position and velocity and control of a missile. Such inertial guidance is particularly desirable in ICBM's, since it is self-contained, not detectable and jam-proof.

• **How system works**—Autonetics' N10 inertial guidance system uses a three-axis gyro stabilized platform holding three induction-type velocity meters mounted on a single frame.

The velocity meter is a single-integrating device; this is mechanized by balancing the acceleration responsive torque on a floated pendulous proof mass, with the eddy-current induction torque created by a rotating constant-intensity magnetic field.

The pendulous proof mass consists of a metallic induction disk, supported eccentrically by means of a hydrodynamic bearing and a position pickoff which senses electrically any rotation of the pendulum resulting from applied torques.

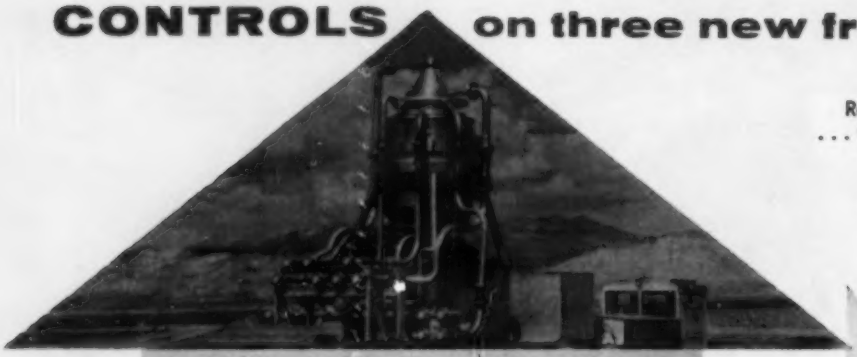
The pick-off signal is amplified and operated on by the servo controller, and the resultant output of the latter excites the magnet-drive motor in such a way that the rotation velocity of the magnets induces an eddy-current drag torque on the induction disk to balance the applied torque due to acceleration. The angle through which the magnets have rotated during a specific time interval is, then, a measure of the time integral of the acceleration along the sensitive axis. This angle is sensed by the output resolver attached to the magnet shaft.

Low cost and producibility are features of this extremely accurate instrument. It offers the particular advantage of having no high-speed rotating parts except under flight accelerations, so that it can be operated for long periods of stand-by on the ground without significant wear.

The stable element subsystem includes the inertial components (gyros

*Project Engineer, Minuteman Inertial Guidance, Autonetics Division of North American Aviation, Inc., Downey, Calif.

AT THE CONTROLS on three new frontiers...



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and acceleration-sensing devices) and an alinement set. The electronic package, consisting of tuning and bridge resistors and amplifier switching electronics for the bubble levels, is also located on the stable element.

The gimbal structure provides the necessary degrees of freedom of the stable element relative to the airframe of the missile. The platform axes are kept parallel to an earth-fixed, launch-point-level, coordinate system, with one axis orientated in the approximate direction of the target.

• **Simplified gyros used**—The free-rotor gyro is a simple device with a minimum number of components, as compared to conventional floated gyros. The gyro is of minimum size and weight, quick warm-up, and adaptability for extensive use under conditions imposing a minimum of handling and adjustment.

Two free-rotor gyros, each of whose rotors spin on a spherical, self-lubricated gas bearing, provide complete attitude references for the inertial platform.

Many of the problems encountered in a liquid-floated gyro—such as convection currents and buoyancy effects, leakage and pump difficulties—do not exist with the free-rotor gyro. Temperature effects are small, thanks to the absence of motor laminations and ball bearings; high rigidity of the rotor is attainable.

Since the rotor is completely nonmagnetic, stray magnetic torques are eliminated. Vibration and bearing noise can be made practically nonexistent with gas spin bearings and, since no wear occurs with such bearings, high reliability and long life are possible. The gyros can operate continuously for many years without wear or performance degradation.

• **Calibration and alinement**—Fully automatic calibration, bias setting and alinement are achieved through a very advanced concept. An alinement unit is mounted on the stable element, consisting of four level detectors on a single mounting block. In addition, phasing networks and preamplifiers are part of the alinement set.

The level detectors furnish information permitting the stable element to be accurately leveled in any of four precisely related orientations. One of these is the flight attitude; the other three are used for calibration purposes.

The alinement unit, together with proper programing of the computer, is sufficient to set the biases, calibrate the inertial instruments and aline the system. Azimuth alinement is accomplished with an autocollimator.

• **General purpose computer**—The airborne digital computer, which plays an important role in the overall inertial guidance and flight control system, is an all-transistorized, general-purpose device. It operates in serial mode and uses a rotating disk-type memory for data storage.

SURE HANDS and dust-free cleanliness are vital in assembly of Autonetics gyro float for inertial navigation.

Advanced transistor circuits and packaging techniques are used to make the computer a miniature versatile unit. The semiconductors are silicon and mesa-germanium-type devices which have very reliable high-temperature characteristics.

An internally-stored program operates the computer, which is filled from punched tape, control panel keyboard, or other input filling devices. The computer accepts information from the velocity meters, angular accelerometers and platform gimbal pickoffs. It uses this data to generate stabilization and steering signals, as well as staging and thrust termination signals. The computer solves guidance equations and flight control equations and supplies prearm signals to the re-entry vehicle.

It also has a number of other uses in the *Minuteman* system. Flight command signals from the computer are transmitted to the nozzle control units, where the appropriate nozzles are moved to direct the thrust vectors of the engines. By continual adjustment of these thrust vectors, the missile is stabilized in yaw, pitch, and roll on the proper trajectory.

Another use is in automatic calibration and alinement of the missile's guidance system at periodic intervals during the ICBM's "ready" life in its silo. By means of a program stored in the computer memory, the settings of the guidance gyros and velocity meters are periodically checked for calibration and alinement. If errors are found, the computer automatically takes corrective action. Following completion of the check, the missile guidance system is ready for instant use.

• **New reliability techniques**—In the *Minuteman* N10 system, the gyros, velocity meters, structural design, automatic alinement procedures and system reliability represent advances in present-generation inertial equipment.

New techniques were developed in using electronic components in the system and controlling the processing of these components in such a way that reliability goals required by *Minuteman* can be met. This called for reliability programs at each of the component manufacturers; at the same time, special handling, marking, testing and burn-in under stringent controls had to be implemented at Autonetics. Emphasis is being placed on reliability, light weight, and ease of maintenance.

Assembly of electronic modules in dust-free areas, and instruction and training of the personnel by means of closed circuit television, are part of the Autonetics reliability program.

The successful tests of early inertial guidance systems indicate that the high-reliability effort now underway at Autonetics and its subcontractors is effective.

System components have been standardized, minimizing the number of different parts. The inertial guidance system uses no potentiometers or relays; all components are electronic. Failure analysis reporting systems and recurrence control are being improved and perfected to assure that detected problems can be solved early in the program.

Special analysis of circuits continues, and engineering changes are incorporated to assure increasing reliability. Electronic components are identified and marked. Special records are kept to follow each component into the final hardware.

When component failures occur, the components can be traced back to a particular manufacturing batch and process. It is possible in this way to identify a bad process, poor materials or insufficient training of personnel at the component vendors.

Seldom before in the use of electronic components has it been possible to keep historic records of all electronic components in an assembly, and to control the product by closing the loop of information back to the component manufacturers and the process by which they were developed. Efforts to simplify the system have improved producibility, operation and maintenance concepts of the weapon system.

Autonetics' efforts are expected to aid the entire military and industry. ⌗

GUIDANCE / SATURN

NASA Ready to Pick Saturn System

Marshall Center and JPL in disagreement over which is best approach

by Jay Holmes

IN THE NEXT few weeks, the National Aeronautics and Space Administration expects to make a series of major decisions on the nature of the *Saturn* guidance system and who is to produce it.

Plans until now had been to produce the system at NASA's Marshall Space Flight Center, Huntsville, Ala., and procure major subsystems and components from industry.

Now, however, there is some consideration of assigning the entire guidance development task to a prime industrial contractor.

Also up for decision is the question of just what kind of guidance system will be aboard the *Saturn*, which carries America's hope for bettering the Soviet Union in launch vehicle power by 1964 or 1965. In part, the question revolves around a jurisdictional question that has developed between two NASA agencies, the Marshall Center and Jet Propulsion Laboratory.

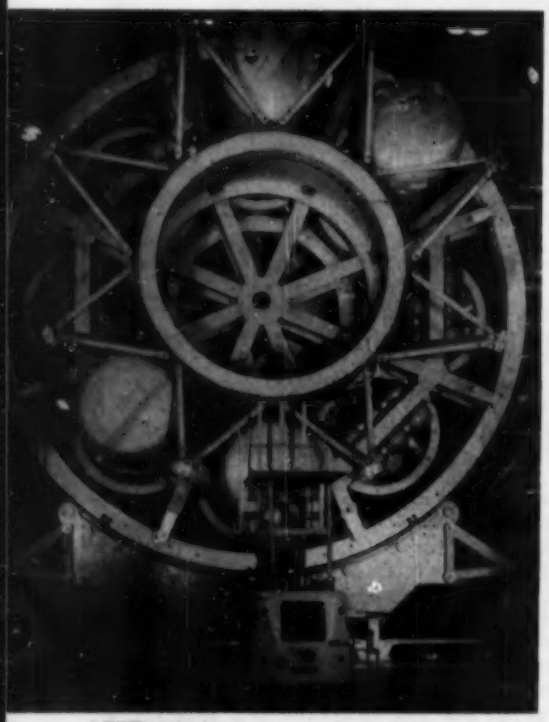
Marshall is responsible for developing launch vehicles and, along with that mission, for guiding vehicles up to the time when they are injected into orbit. JPL is charged with developing spacecraft for deep-space missions—such as to the moon and the planets—including the guiding of spacecraft on deep-space trajectories.

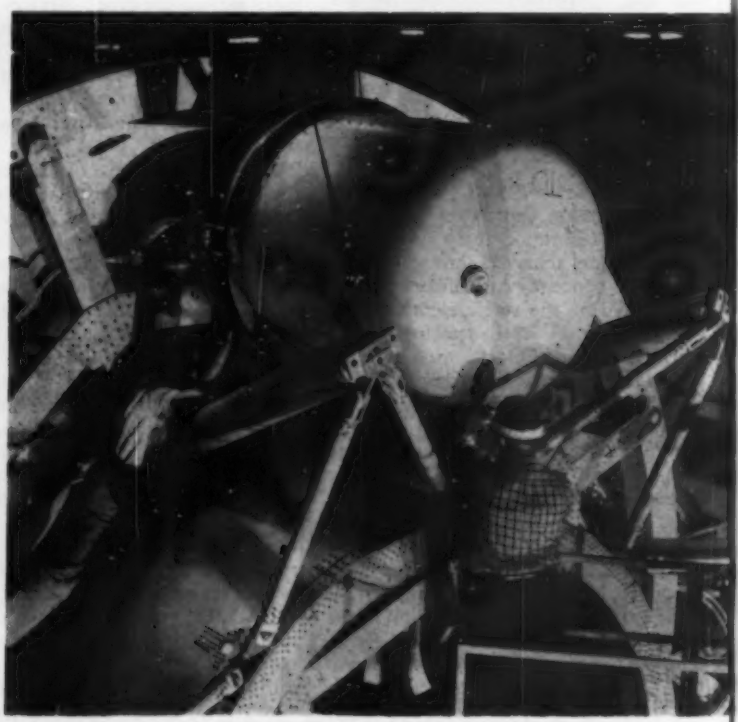
Wernher von Braun, director at Marshall, contends it is wasteful to use a guidance system—including an extremely sophisticated computer and other components—just for carrying a space vehicle up to the point of injection into a deep space trajectory, and then fail to make further use of it.

JPL spokesmen have not commented publicly on the question. However, it is understood they feel that guidance in deep space imposes special requirements that are not best met by systems designed for launch vehicles.

• **Upward progression**—During the test phase of the *Saturn* vehicle, the guidance package will be moved upward as live stages are added. *Saturn* is scheduled to have 10 flight tests between 1961 and 1964. The first three will be live boosters with dummy second and third stages. Next will be a series of live boosters with live second stages consisting of the S-IV LOX-liquid hydrogen vehicle being developed by Douglas. Then will be a series of tests with three live stages, by adding the S-V modified *Centaur* vehicle, being developed by Convair. *Saturn* 10 will be a prototype operational vehicle.

In the first three flights, the guidance package is to be carried in an adapter ring atop the first stage. On the next three, it will go onto the second stage. From the seventh flight on, it will be on the final stage.





LEFT: *Workman installs one of four guidance-telemetry packages on flight Saturn.* **RIGHT:** *A closeup of the package, four feet in diameter and 4½ feet long, which will monitor engine performance and signal necessary swiveling of outer four engines.*

On the early flights, guidance will be combined with an extensive telemetering package, to monitor engine performance. The equipment will be installed in four cylindrical capsules roughly 4 ft. in diameter and 4½ ft. long.

Many fundamental features of the control system of *Saturn* will result from adapting components used in the *Jupiter* to meet the needs of the bigger vehicle. However, rate gyros will be added as sensing elements—a major departure. The big *Saturn* vehicle is somewhat flexible and may bend under stress. Rate gyros will make it possible to do a better job of stabilization.

• **Prime goal**—The *Saturn* guidance itself has the major objective of providing a universal system capable of performing many mission requirements in support of payload objectives, *Saturn* Systems Chief Oswald H. Lange says. Guidance will be all-inertial.

The first responsibility, of course, will be to monitor and correct performance of the eight engines of the booster stage. Four of the engines will be mounted solidly in a central square. The remaining four, on an outer ring, can be swiveled to correct the flight trajectory.

The control information will be active on all flights. If one engine goes out, propellant will be distributed to other engines.

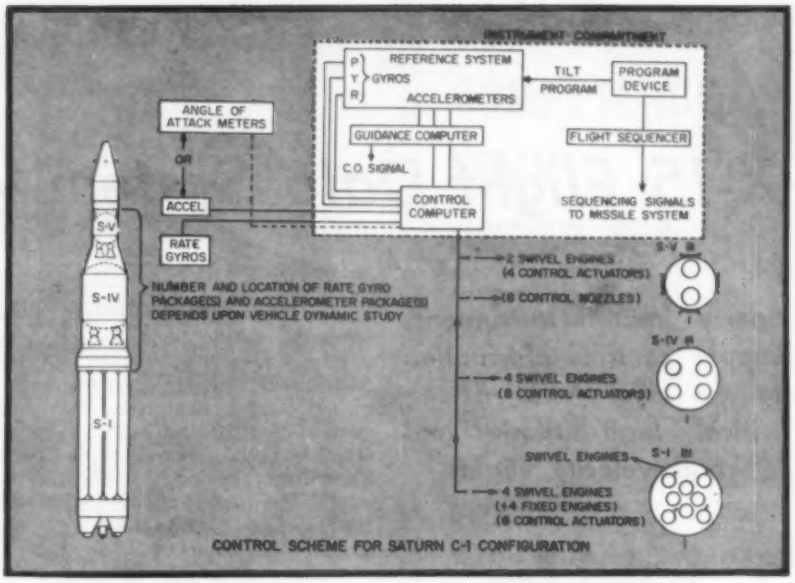
However, on the first three flights the *Jupiter*-type platform will be active only for engine control information. Guidance information will be telemetered back to ground stations.

• **There'll be some changes**—Regardless of the decisions taken in the next few weeks, it seems certain that some sort of advanced guidance system will be aboard in later flights. The nature and timing are up for decision.

Early in January, before NASA decided to review the entire *Saturn* guidance question, Walter Haeussermann, chief of the Marshall Center Guidance and Control Division, said a simple guidance computer was to ride as a passenger on flights 4-6, telemetering data back, and become active on flights 7-10.

Under the old plan, an advanced form of stable platform was to ride as passenger on flights 4-10 and become active with flight 11, the first operational *Saturn*. The same plan was envisioned for an advanced, highly sophisticated guidance computer. If the entire package were not ready by flight 4, the idea was to start flying components then and work up to an entire system as soon as possible.

The early *Jupiter*-type inertial guidance unit is manufactured by Sperry-Farragut Division of Sperry Rand. The gyros are standard, air-suspended units with one degree of freedom. The inertial elements are fully gimballed. Control information is provided by yaw, pitch and roll accelerometers. Corrections are made through a hydraulic system powered from a gas turbine.



CONTROL SCHEME FOR SATURN C-1 CONFIGURATION

• **Outside gimballing?** — An advanced system under current study has the goal of greatly reducing size, weight and power requirements. For greater flexibility, Hauessermann said, it should be outside-gamballed, so as to allow much more angular freedom than the *Jupiter*-type, intended primarily for a ballistic missile.

The Marshall guidance chief foresaw the likelihood of early mid-course guidance in the third stage, followed by radio vernier control of the spacecraft on deep-space missions. However, NASA headquarters may decide that is part of the JPL mission.

Under the old plan, the first two stages of *Saturn* were to yield to early perturbations of wind and thrust, except to swivel engines for control. With three live stages, the first corrections of the flight course itself were to be made after second-stage burnout.

On the first-stage tests, eight *Pershing*-type telemetering transmitter packages, each about 1 cu. ft. in volume, will be used with 216-channel multiplexers to combine signals from about 600 transducers and other sensors. With live second and third stages, 700 to 1000 different measurements will be made during each flight. Haeussermann figures the cost of this part of the program at about $600 a measurement.

In January, two types of computers were under study for the job of providing a high-speed digital system for both guidance and control. One, by International Business Machines, is a small, somewhat advanced solid-state system like that IBM supplies for *Titan II*. The other is a more conventional computer Librascope is supplying for *Centaur*. One of the two was to be carried as passenger of flights 4-6 and become active on flights 7-10.

The plan was to award contracts in late 1961 for study of the advanced digital computer, which would use advanced solid-state concepts, have enlarged capacity and be greatly reduced in size. The aim would be for extreme reliability.

The computer would not give separation instructions to the *Saturn* booster. Separation was to be accomplished instead by programed timers connected to fuel-level sensors.

Power would be supplied to the guidance and control system from batteries and a 1-kilowatt rotary inverter. A static inverter and battery pack are in development. The guidance and control equipment will use less than 750 watts, leaving 250 watts for the telemetry and hydraulic measuring units. A hot-gas turbine will provide power for hydraulic control actuation.

The first-stage telemetry package is being developed by Motorola. National Data Systems Inc., Dallas, is supplying the 216-channel multiplexer.

In the second stage, sub-contractors for Douglas on electronics include Applied Science Corp., Princeton, N.J.; Electro-Mechanical Research Corp., Sarasota, Fla.; and Bendix. ⌗

X-15 Flight Data System—A Precursor

Sperry inertial instruments supply control information to the pilot—vital during critical high-altitude and high-velocity flight

by John F. Judge

THE FORERUNNER of future aerospace vehicle flight data systems directs *X-15* pilots as they put the rocket plane through its paces.

An inertial all-attitude flight data system, designed and built by Sperry Gyroscope Co., division of Sperry Rand Corp., provides the pilot with the information necessary to control the craft at speeds up to 4000 mph and altitudes of 100 miles.

Each component—and the entire system—can withstand accelerations of more than 10 g and function perfectly in weightless environments.

In addition to supplying inertial information for the cockpit instruments, the system's sensors and computer feed data to specialized airborne and ground recorders.

EXTREME ACCURACY and reliability of the X-15 inertial system was determined on this "stable table" set-up. The system is designed to operate within the X-15 in conjunction with four flight instruments which aid in the piloting.

Four general types of instrumentation were originally considered by Sperry for the North American *X-15*: pressure instruments, radar or radio, simple gyroscopic and inertial.

The inertial system was the only one that could handle all the required measurements of velocity, altitude and attitude angles. In addition, the single limiting factor inherent in the inertial system was its flight duration. But it was possible to develop inertial components adequate to the mission of the *X-15*—an operating life of 1000 hours.

• **Twin functions**—The *X-15* Inertial All-Attitude Flight Data System can be functionally divided into two groups. One section is carried in the *X-15* itself and consists basically of the stabilizer, computer and indicators. This equipment supplies all of the required data after the *X-15* is launched.

The second group is carried in the B-52 launching aircraft. This equipment is used to supply the proper initial conditions to the computer and thus align and stabilize the platform prior to launch.

The data insertion equipment was located in the B-52 to save overall weight in the rocket plane and to relieve the *X-15* pilot of any duties in the pre-launch phase.

The inertial system is composed of the stabilizer, which contains the sensory elements, and the computer, which processes data from the sensing elements to derive velocity, position and altitude data.

The platform is maintained normal to the geographic vertical and, because of the extreme altitude and velocites of the plane, all accelerations due to kinematic velocities and changes in the earth's mass attraction are computed and inserted into the system.

• **Gimbal complex** — Four distinct axes of rotational freedom are present in the stabilizer. The sequence of rotational freedom from the case inwards are roll, pitch, inner roll and azimuth. The pitch, inner-roll and azimuth axes are mutually perpendicular. The outer-roll axis is gimballed with respect to the fore-aft aircraft axis and operates

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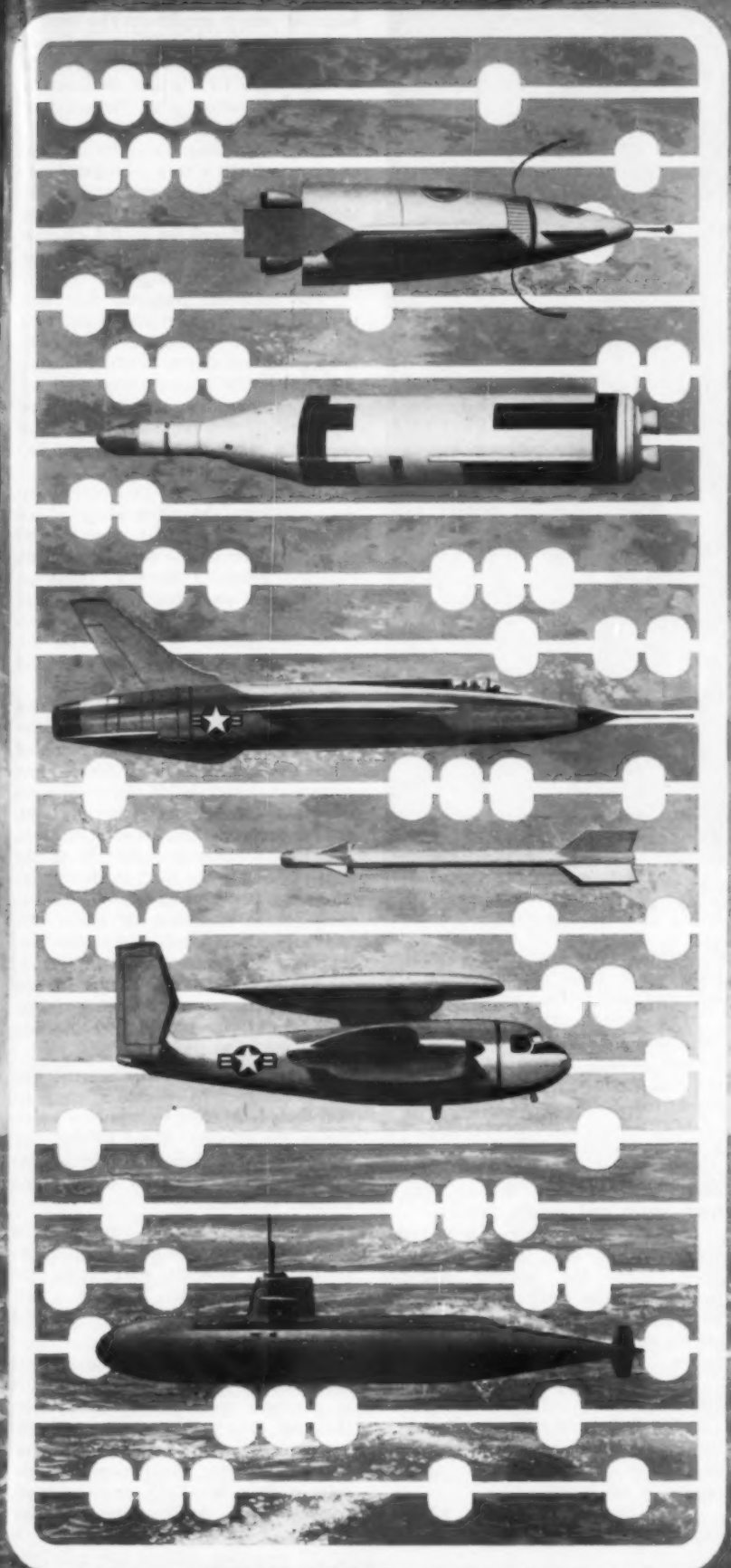

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HOT NOSE DEVELOPED by Northrop's Nortronics Division senses angles of attack and side slip during exit and entry phases of X-15 flight.

in conjunction with the inner-roll axis to produce an angular displacement proportional to aircraft roll attitude.

The redundant roll axis allows the aircraft unlimited maneuvering about any degree of freedom without the possibility of gimbal lock or loss of verticality.

Basically, the gimbal design consists of direct-drive torquers and single-speed readout synchros mounted at each end of slightly elliptical gimbals. The servo amplifiers for each axis are transistorized and mount directly on the gimbal being driven. The gimbal itself is used as a heat sink for the power transistors, reducing the number of required slip rings.

The torque capability of each gimbal axis torquer varies between 1½ lb.-ft. for the outer-roll axis to ¾ lb.-ft. for the inner-roll and pitch axes. The azimuth axis requires a smaller torquer, 0.3 lb.-ft., because of lesser dynamic requirements.

This design approach essentially eliminates gearing on the gimbal axes and has the advantage of minimizing disturbance forces acting on the platform under flight conditions. It also enhances performance under vibration.

The gimbal servo response is on the order of 40 cps, since design limitations usually caused by shaft flexure and gear backlash are essentially eliminated.

Sperry says that isoelasticity was a prime consideration in the gimbal structure, and a symmetrical gimbal design resulted from this as well as from space and weight factors.

• **Platform assembly**—Three linear accelerometers and three integrating gyros form the sensing elements mounted on the platform. Ten transistorized amplifiers are required to operate the sensing elements and the gimbal servos.

Three 10^{+5} gm-cm²/sec. floated rate-integrated gyros are used with associated heater amplifiers to maintain the operating temperature within narrow limits. A Sperry linear accelerometer is employed.

This consists of a test mass, a capacitive sensing element and a force balanced servo amplifier. The output of the instrument is a DC current proportional to acceleration. The threshold is better than 10^{-6} g and its accuracy without calibration is of the order of 10^{-4} g.

The case design consists of two concentric shells with a corrugated surface. These corrugations considerably increase the area of heat conduction from the platform air to the external cooling air. Thus the case configuration serves as a heat exchanger.

The computer performs the functions of Doppler inertial mixing, gyro drift storage, acceleration-to-velocity integration, velocity-to-position integration, earth-rate computations and acceleration corrections due to kinematic velocities. System noise and weight are kept to a minimum, by means of DC analog computing techniques.

The computer uses two basic computing blocks. One is a precision integrator that utilizes a Sperry DC tachogenerator as the fundamental accuracy-determining element. These integrators are packaged in two groups of three each, with all necessary electronic equipment included. This arrangement simplifies maintenance and test procedures.

Similar packaging concepts are used with the second computing element, an integrator used to erect and align the platform. The acceleration corrections and earth-rate computations are accomplished passively with resistor networks and potentiometers.

The computer is connected to the control panel in the B-52 mother plane. The panel performs system mode selection, manual insertion of initial altitude and position data and system performance monitoring prior to launch.

It also contains the converters and couplers necessary to introduce the initial velocities and heading angle into the system for alignment purposes.

Within the *X-15*, the inertial system is designed to operate in conjunction with four flight instruments which aid in the piloting. Three of these instruments were specially designed for the *X-15*; the fourth is a three-axis attitude indicator.

One of the special instruments is a self-contained altitude indicator operating on synchro data from the computer. The other two are a vertical velocity indicator and a total velocity indicator.

The vertical velocity indicator is used during high-speed, level runs. It is a simple meter-movement type instrument. The total velocity indicator is a computing mechanism which receives the three components of the velocity from the *X-15* inertial system. derives and displays total vector velocity. ¤

Dyna-Soar to Depend on Proven Parts

Honeywell is developing primary subsystem for boost-glider and producing flight controls for space vehicle

by Paul Yingst
and
Charles L. Seacord*

ENTIRELY TRIED and proven hardware is the byword for *Dyna-Soar's* guidance and control system selection.

Dyna-Soar, a manned, delta-winged glider boosted into orbit by a modified *Titan II*, must be able to re-enter the atmosphere and land at any suitable airfield chosen by the pilot within a circle of maneuverability several thousand miles in diameter.

Its range of speeds will extend from over 15,000 miles an hour in orbit down to a landing speed of less than that of some of our present combat aircraft.

Minneapolis-Honeywell Regulator Co. recently was named an associate prime contractor by the Air Force Aeronautical Systems Center, Dayton, Ohio, to develop the primary guidance subsystem for the boost-glider, and more recently was selected by Boeing as subcontractor to produce the flight control electronic subsystem for the space vehicle.

It is significant that the guidance and control challenge will be met with equipment that is almost entirely tried and proven today; in fact, much of it has long been in mass production.

The principal components to be furnished by Honeywell include a 4-gimbal inertial platform, a platform electronics package, a digital coupler and power supply, a malfunction detector, a computer, and the automatic flight control electronics subsystem.

The inertial platform, together with its electronics, digital coupler, and power supply, is the same as that designed by Honeywell for *Centaur*. Its gyros are of a type which has been in production since 1957.

The computer for the inertial guidance subsystem has not yet been announced, but it will be one already in production and currently in use.

The flight control subsystem is basically the adaptive autopilot which Honeywell has spent 7 years developing and flight testing.

• Initial start in '56—Honeywell's contribution to the *Dyna-Soar* program may be said to have begun in 1956 when the Bell Aircraft Company (now Bell Aerospace) chose the company as guidance system manager for the "Orbital Glider" program. The selection was followed by five years of design study, much of it company-funded.

During the same period, design and development work was carried out on both guidance and automatic flight control systems of the types needed for other high-performance aircraft and spacecraft. Systems designers gained particularly valuable experience in the course of developing inertial navigation systems for the Army's *AN/USD-5* and *AN/USD-4* high-performance jet drones.

But the development that proved to be of the most direct value to the *Dyna-Soar* program was the inertial guidance equipment developed for Convair for use in the second stage of the NASA *Centaur*.

The direct forerunner of the adaptive flight control subsystem which will be produced for *Dyna-Soar* is the autopilot system which is scheduled to be test flown in North American's No. 3 *X-15* in September of this year.

Funded by a WADD contract for an "Adaptive Flight Test Vehicle for an Advanced Electronic Flight Control," the development and design has progressed into hardware which is now in the qualification and reliability testing phase. Since the *X-15*, like *Dyna-Soar*, must function both as an aircraft and as a spacecraft, many of its design problems are similar; the WADD program has resulted in a solid basis for the development of the *Dyna-Soar* flight control electronic subsystem.

(These adaptive systems are both descendants of Honeywell's MB-5, being produced under an AMC contract for F-101B aircraft.)

Development of the adaptive autopilot system for the *X-15* began nearly seven years ago with Honeywell-financed research directed toward evolving a flight control system which would result in uniformly satisfactory performance, over an extremely wide range of flight conditions, with no dependence upon air data scheduling of system gains.

After the feasibility of the research-developed adaptive system was shown analytically, the Air Force recognized the potential of such a control system, which would automatically accommodate the enormous range of flight conditions to be encountered by more advanced vehicles. It supported pitch-axis feasibility flight tests of the autopilot in an F94C.

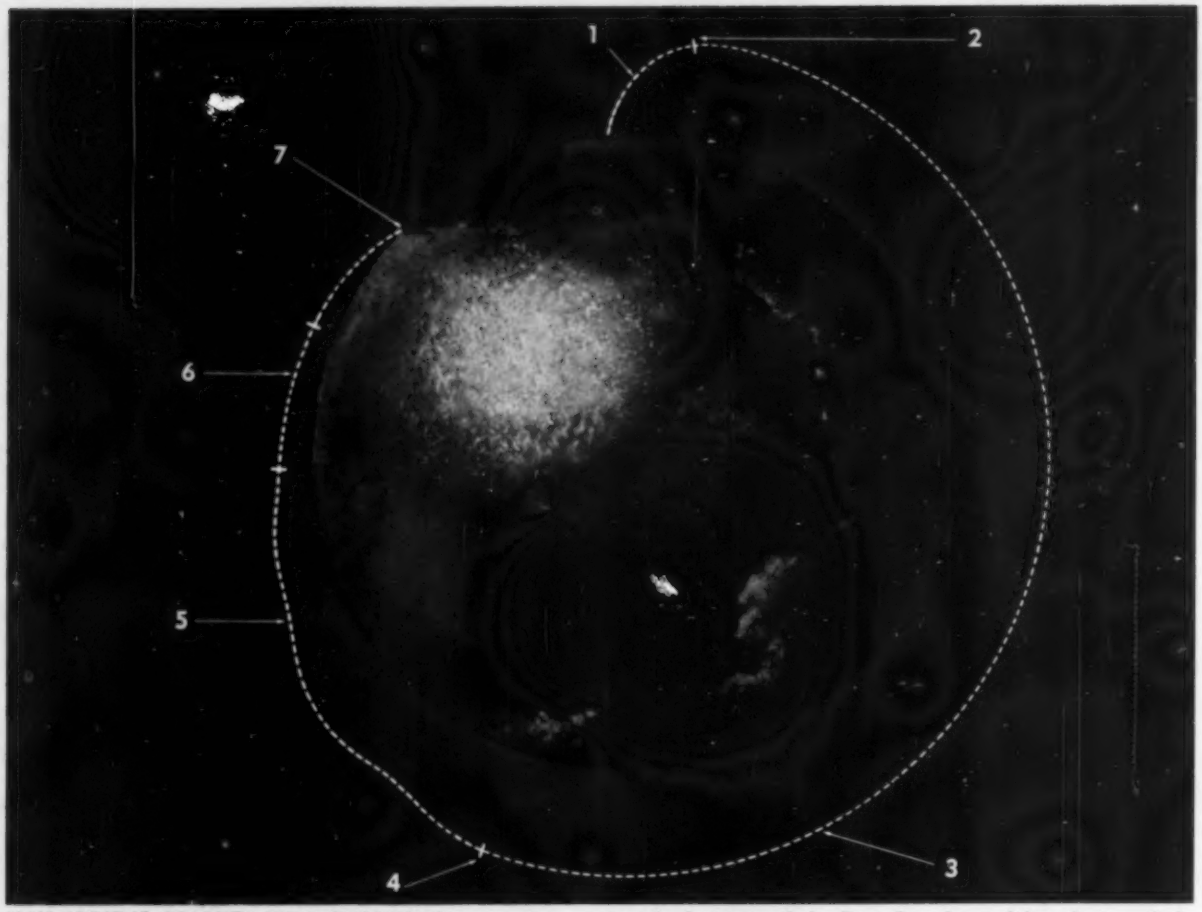
Further work was started on a complete three-axis adaptive autopilot, including outer-loop modes of heading, attitude and altitude-hold and control-stick steering. This autopilot, the M-90, was flight-tested in an F101A in the summer of 1959.

The system included, for the first time, high-frequency magnetic amplifier mechanization which is to be an essential part of the *Dyna-Soar* system. Solid-state switching concepts were employed as extensively as the state-of-the-art would permit.

• A blend of technologies — The blending of aerodynamic and reaction

* *Mr. Yingst is program director, Dyna-Soar primary guidance system, Minneapolis-Honeywell, Aeronautical Division—St. Petersburg, Fla.*

Mr. Seacord is project manager, Dyna-Soar flight control electronic subsystem, Minneapolis-Honeywell, Aeronautical Division—Minneapolis.



NON-ORBITAL FLIGHTS WILL FOLLOW this operating sequence in first tests of the Dyna-Soar boost-glider: (1) Launch by Titan II booster from Cape Canaveral; (2) Separation—inertial guidance and flight control systems take over; (3) Guidance and control systems keep the craft in its required flight path; (4) Initiation of re-entry into the atmosphere from space; (5) Re-entry maneuvers within the safe flight corridor; (6) Dissipation of surplus energy and reduction of speed, and (7) Touchdown at Edwards Air Force Base, Calif.

controls for *Dyna-Soar* poses a particularly interesting problem.

The use of reaction control for vehicle stabilization and maneuvers requires the expenditure of considerably more power than that required to perform the same task through aerodynamic controls, provided the aerodynamic controls are sufficiently effective to perform the task. For this reason, a system for *Dyna-Soar* has been devised that will make maximum use of aerodynamic controls and will use reaction control only when the aerodynamic control effectiveness falls below a set value, and when under normal operation the error signal in any axis exceeds a predetermined amount.

The key element within the adaptive control system is an automatic gain changer working in conjunction with a self-evaluating control loop. The output level of the gain changer is inversely proportional to the aerodynamic control surface effectiveness. When the gain-changer output level exceeds a given value, the reaction control system is switched in; when it drops below a second predetermined level, the reaction control system is switched out.

In simulation studies the optimum switch-in and switch-out levels have been found to be separated by 20% of the total gain-changer output range. This difference is required to prevent oscillation between the two control conditions.

To accommodate the situation in which the error signal exceeds the present value, the system includes an electronic deadband in the switching amplifiers which drive the on-off reaction valves. This arrangement prevents a slight error between the actual and the the desired system performance from activating the reaction controls.

Finally, the system uses integrating servo amplifiers to insure minimum system error and maximum automatic aerodynamic trim, so that the aerodynamic controls have full authority to null any system error signal before the reaction controls are used.

The adaptive system uses 3.5-kc magnetic amplifiers as the basic electronic building blocks in bridge signal amplifiers, operational amplifiers, and various other functions. These magnetic amplifiers are inherently reliable devices and display extremely low drift rates with a null shift of less than 1 microampere of equivalent input current over a temperature range of −55° to +125°C. Compensated amplifiers with matched cores can reduce even this drift by a factor of up to 4.

The frequency response of the 3.5-kc magnetic amplifier is approximately 10 times that of its 400-cycle counterpart and its size about ¼.

Where transistor application is necessary, the solid-state device is operated in its switching mode rather than linear fashion when possible. Significant improvement in reliability has been accomplished with this technique.

• **First test flights**—*Dyna-Soar 1* will not be orbital, but it will fly through an extremely wide set of flight conditions, from high supersonic

(Continued on page 51)

Microdot Appoints Avnet for Multi-Pin

LOS ANGELES – An exclusive long term agreement for the distribution of Microdot's new microminiature Multi-Pin connector series has been awarded by Microdot to Avnet Electronics Corporation.

Microdot's Multi-Pin is only one-quarter the size of present "miniature" types and features complete interchangeability of parts. Multi-Pin inserts are available in a variety of straight power, straight coaxial, and combination power-coaxial layouts. Power contacts are interchangeable without changing inserts, allowing hermaphroditic contact arrangements to be set up (a mixture of male and female contacts within the plug or receptacle, allowing hot leads to both plug and receptacle).

Available in three shell sizes, Microdot's Multi-Pins can contain up to 61 power or 19 coaxial contacts in a 1¼" shell.

According to Microdot, Avnet will supplement Microdot's sales engineers and seventeen sales representatives with their own sales engineering staff and provide an extremely well organized and broad based national distribution from Avnet's eight stocking locations. The agreement applies to the standard line of cylindrical Multi-Pin connectors, with a separate non-exclusive agreement covering other types and Microdot's coaxial connectors and cable. Present distributors for Microdot will continue to carry the standard line of coaxial connectors and cable on a non-exclusive basis.

Avnet currently has a large initial Multi-Pin stocking order in each of their facilities for immediate delivery. Future orders are expected to be substantial.

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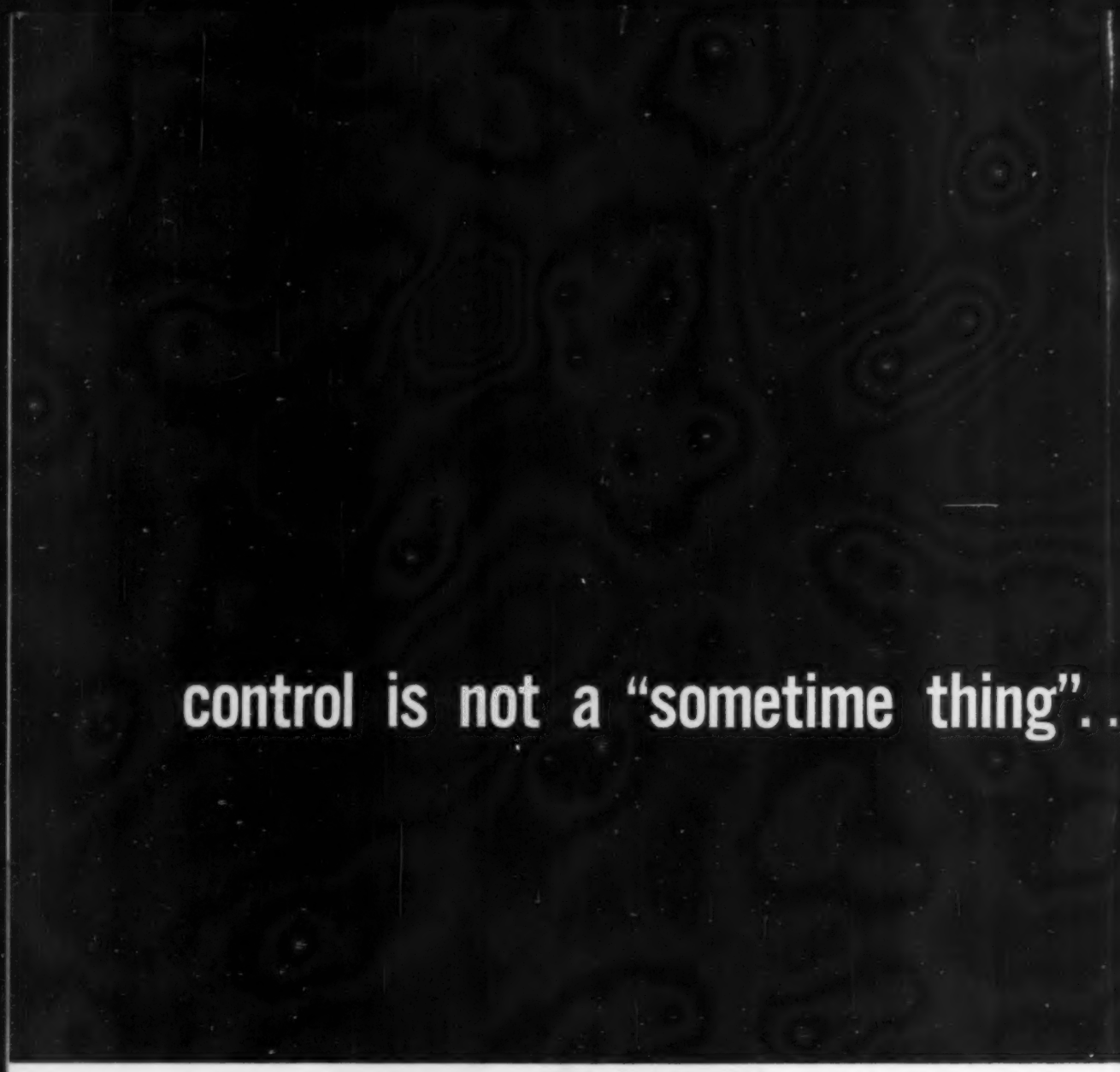

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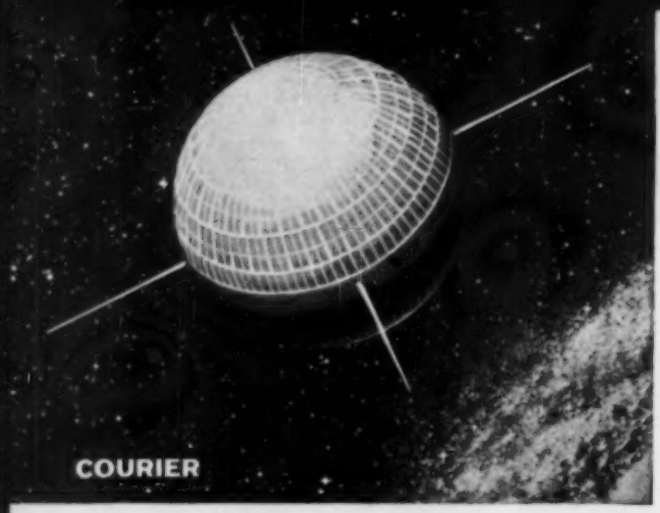

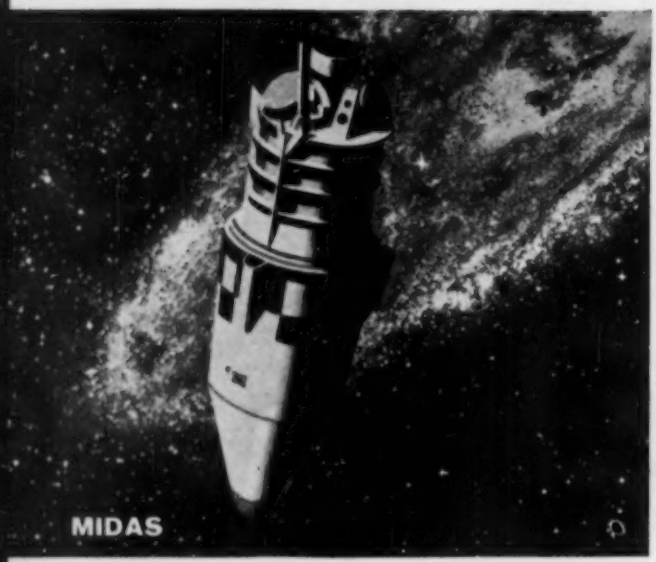

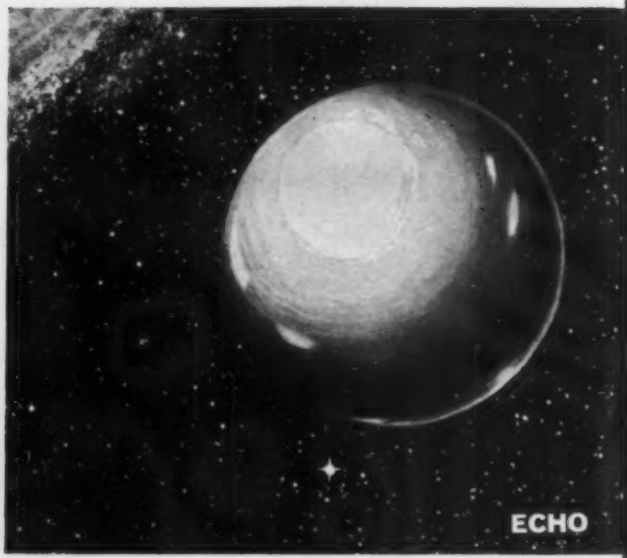

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(Continued from page 46)

speeds at low altitudes where control surface effectiveness is extremely large to altitudes so high that only reaction control is effective in controlling attitude.

Re-entry presents difficult problems in both vehicle protection and pilot safety, as well as equipment environment. The flight control electronic system must control the aircraft within a narrow-flight-condition corridor whose boundaries are set by both structural and temperature limitations.

The necessary limiting of normal load factor and critical temperature will be accomplished by the technique of feedback limiting, drawing heavily from the philosophy used on the MB-5 autopilot for the F101B. Inert gas cooling will be used for the electronic equipment.

• Guidance reliability paramount—In studying the *Dyna-Soar* inertial guidance subsystem requirements, Honeywell considered that the specifications called above all for proven hardware which would require a minimum of modification. The selection had to be made from three guidance systems then in production.

The choice fell to the platform developed for the *Centaur* for the following reasons:

–It was based on a gyro (the GG8001) that had been in production since 1957. Over a thousand of these had been made.

–Its platform, with provisions for both gimbal flip and electrical flip, has the most nearly perfect all-altitude capability.

–It includes all the mirrors and the prism required for complete field checkout, test, calibration, and alignment.

The inertial platform is a 4-gimbal assembly using three Honeywell miniature integrating gyros (GG8001B1) and three Honeywell pendulous accelerometers (GG116A2). The gyros and their associated gimbal-drive servo loops serve to keep the first (azimuth) gimbal in a fixed relationship to inertial space, which is the prime reference for the guidance system.

The accelerometer is relatively new, but more than a hundred of them are already in use.

The primary function of the inertial guidance subsystem, during the boost phase, is to guide *Dyna-Soar* onto the correct trajectory for accomplishing its mission. To do this, it senses the acceleration inputs, determines the platform and vehicle attitude, generates the steering commands for transmission to the flight control system, and finally commands the engine cutoff when the programed velocity and attitude conditions are met.

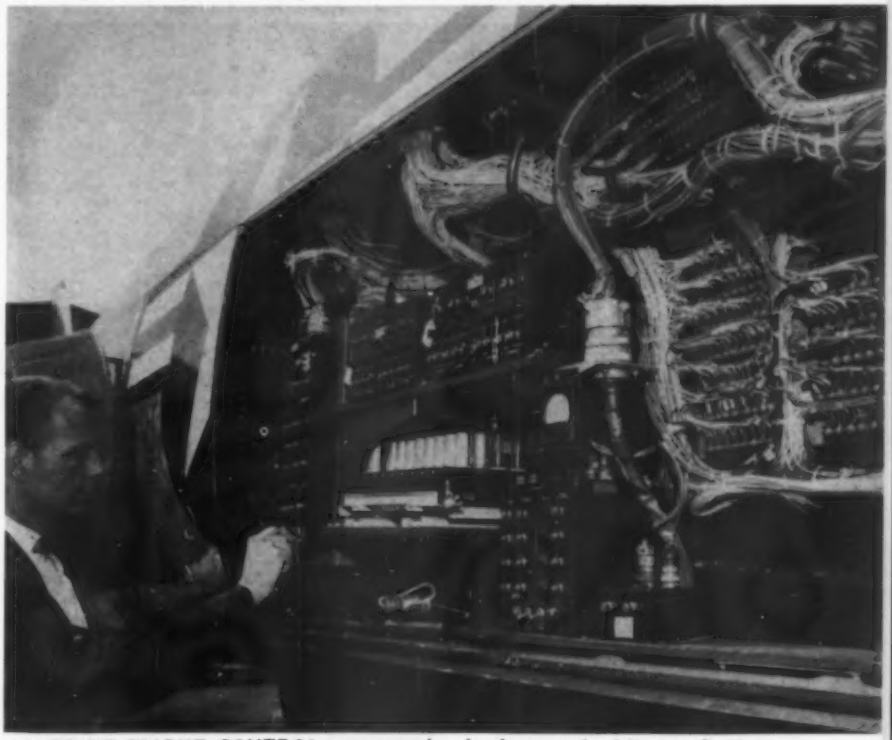
During the sub-orbital flight phase and re-entry, the main function of the inertial guidance subsystem is to provide the computation necessary for guidance and energy management in all phases of flight.

•Computer selection—The selection of an airborne digital computer for the inertial navigation subsystem turns mainly upon the following factors: Proven reliability, which together with a good production history is the most important criterion; capacity and speed; compatibility with Honeywell guidance equipment; and adaptability to the problems presented by launch site loading and airborne power interruption.

Within the guidance system, the computer will continuously compute and provide as outputs for display a number of quantities that may well exceed 19 or 20. The range of these is from the relatively simple attitude indications to complexes such as the glider's geocentric latitude and longitude.

Extremely high mission reliability is a requirement for *Dyna-Soar*. To achieve very high reliability without compromising fail safety, the Honeywell adaptive system makes use of the compensating features of a self-evaluating loop. This arrangement will compensate for any system gain reduction resulting from an open signal failure in one channel, and it uses relatively simple fault detection and isolation circuits, since only hardover failures require specific disconnection. In this way the conventional multiple redundancy which improves fail safety but reduces reliability is replaced with a dual redundancy arrangement which, in the adaptive loop, increases both.

Since *Dyna-Soar* will be an unpowered glider during most of its flight, its "energy management" will be of crucial importance. Very rapid and accurate correlation must be made continuously between the amounts of kinetic and potential energy remaining, and these energies must be used or dissipated in such a way that the pilot is allowed a maximum of descent and landing maneuverability.



ADAPTIVE FLIGHT CONTROL system under development by Minneapolis-Honeywell for Dyna-Soar is an outgrowth of, and will be very similar to, that used in Air Force F-101 Voodoo jet interceptor shown above. Essentially an autopilot, the system adapts itself electronically to its environment during flight.

The energy management concept to be employed is one in which the envelope of maximum maneuvering capability of the glider is continuously computed. The result of this computation may be presented as an "energy fan" in which maximum range is achieved by flying at maximum lift-over-drag ratio, and minimum range by flying at the maximum coefficient of lift.

The trajectory that will give the maximum maneuver capability will then maintain the destination point at the center of the energy fan. ⌗

Gyros Vary Widely

(Continued from page 23)

a two-axis rate gyro with a mercury rotor which is driven by a rotating magnetic field. A rotation about an axis other than the spin axis causes a differential pressure in the spinning mercury along the spin axis. A pressure transducer serves as the output.

In the field of high-accuracy gyros, there is a sharp divergence of opinion on what is the best approach.

The Army Ballistic Missile Agency has committed itself to the position that gas-bearing gyros are the best. This is a reflection of the fact that much of the work done at ABMA is a continuation of the German *V-2* program. The *Redstone, Jupiter,* and *Explorer* satellites all attest to the effectiveness of this approach. These gyros were built first by Ford Instrument and later by Sperry-Farragut Division of Sperry Rand. The new Army *Pershing* missile has a guidance package which utilizes gas-bearing gyros built by Bendix-Eclipse Pioneer Div.

The MIT Instrumentation Lab, under the direction of Dr. Charles S. Draper, is equally committed to the belief that fluid-floated gyros represent the most promising way to obtain higher-accuracy gyros. The Air Force and Navy have supported Dr. Draper's position.

The *Thor, Titan, Atlas, Mace,* and *Polaris* guidance packages all employ fluid-floated gyros as the basic reference.

However, there is no question that each represents a satisfactory solution. Interestingly enough, private companies originally tended to support the position of their customers but have now begun designing and building both fluid-floated and gas-bearing gyros—and in at least two cases, a combination of both.

A discussion of the relative merits of each approach might well be in order. The objective is to reduce to as low a level as possible the precession axis torques. By flotation to zero buoyancy there should in effect be no load on the bearings.

In the floated gyro, the rotor is floated in an outer case. This can be a single-degree-of-freedom gyro such as designed by MIT, or a two-degree-of-freedom gyro as built by Litton Industries and American Bosch Arma.

The use of a flotation fluid requires very close temperature control lest the density of the fluid change with temperature and introduce an error. Thus temperature-control circuits are an indispensable requirement of fluid-floated gyros.

One of the areas being pursued by many firms is devising flotation fluids which are less sensitive to temperature variation.

There are two types of gas bearings: hydrostatic and hydrodynamic. Hydrostatic bearings require an external source of pressure, usually a small integrally mounted compressor. Hydrodynamic bearings do not require an external pressure source but in effect produce the necessary supporting pressure by virtue of the relative motion between the journal and bearing.

The hydrostatic gas bearing is used in the same manner as the fluid in a floated gyro (to support the rotor) and has the advantage of being less temperature sensitive. However, it is susceptible to contamination from the compressor supply.

The hydrodynamic gas bearing is growing in popularity as a pure design and also in hybrid form. Both Minneapolis-Honeywell and Kearfott have developed hybrid floated single-degree-of-freedom gyros. These use hydrodynamic bearings on the rotor spin axis instead of conventional ball bearings, plus flotation of the rotor assembly in the conventional manner.

The advantage over ball bearings of such an arrangement lies in the absence

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of metal-to-metal contact during the operation of the spin-axis gas bearing.

In theory, a gas bearing, both hydrodynamic and hydrostatic, has no life limitation due to wear. However, the limiting factor in a hydrodynamic gas bearing is the number of starts that can be made without ruining the bearing surface.

Where quick warmup or instant readiness is required, running the gyro motor continuously becomes attractive; it is in this application that these gyros will be most useful. They also yield a much cleaner output signal due to absence of bearing noise, with a consequent improvement in drift performance.

The Minneapolis-Honeywell gyro is almost entirely of ceramic construction while the Kearfott gyro limits the use of ceramics to the spin bearing.

The advantage of using ceramics for the bearing surface only is that a higher angular momentum can be obtained in the same size float. A surface hardness in excess of nine on the Moh scale is required for the bearing; while it can be obtained with metal, ceramics offer the additional advantage of freedom from galling.

Ceramic gas bearings have been started hundreds of times with no perceptible wear, even when viewed under a microscope. However, the entire gyro assembly still needs a precise temperature control.

A gyro possessing high-performance capability which uses hydrodynamic bearings and no flotation is being employed in the *Minuteman* guidance package. It was designed and built by Autonetics. This is a two-axis, free-rotor gyro with a spherical hydrodynamic bearing.

In effect, the gyro has three degrees of freedom—unlimited freedom about the spin axis and limited freedom about two orthogonal output axes. Its use in the *Minuteman* provides the desired instant readines by continuous running of the rotor.

A similar gyro is being built by Kearfott for the Navy.

The hydrodynamic gas bearing is not a panacea for all applications. Properly used, it presents a very attractive technical approach for improving gyro performance. In space vehicle applications, however, where long flight duration is required, gas-bearing rotors undoubtedly will be used in the gyroscopes.

Efforts are being made to improve the performance capabilities of proven gyros by adapting some new error compensation techniques. One of these, used by Sperry and others, involves rotation of the gimbal bearings in an effort to average out or accelerate the averaging effect of the random gyro torques.

This technique is effective and can yield a non-floated gyro having a drift rate of better than 0.5 degree/hour with a wheel angular momentum of 8×10^6 gram-cm^2/sec.

Another technique uses case rotation of a two-degree-of-freedom gyro about an axis colinear with the gyro-rotor spin axis, which serves to average out unbalance forces about that axis. This scheme is used by Bell Aerospace in their Hipernas floated gyro and by Kearfott in both a floated and non-floated gyro.

Two other compensatory techniques used to improve gyro performance are feeding back accelerometer signals to compensate for acceleration sensitive gyro errors, and using intentional thermal unbalance to center floated gyros.

The performance of a stable platform can be no better than that of the gyro sensors. However, the inherent performance capabilities of a gyro may be compromised by an improper gimbal structure. Therefore, some investigators, attracted by the opportunity to get rid of the gimbals, have produced gimballess platforms.

There are two approaches. One scheme is predicted on the two-concentric-spheres arrangement. The inner sphere contains all the sensors and is

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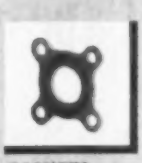

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suspended relative to the outer sphere, but possesses angular freedom of movement.

The main difficulty with such an arrangement is not so much in the suspension as it is in the means of transferring power and data between the inner and outer spheres. It seems unlikely that such a scheme will be applied to operational hardware in the near future.

A more attractive scheme—one which is being actively pursued—is known as the body-mounted or gimballess system, mentioned earlier. Here, the gyro sensors are rigidly mounted to the airframe and the output signals are fed to a computer which simulates by computation the functions of the gimbal.

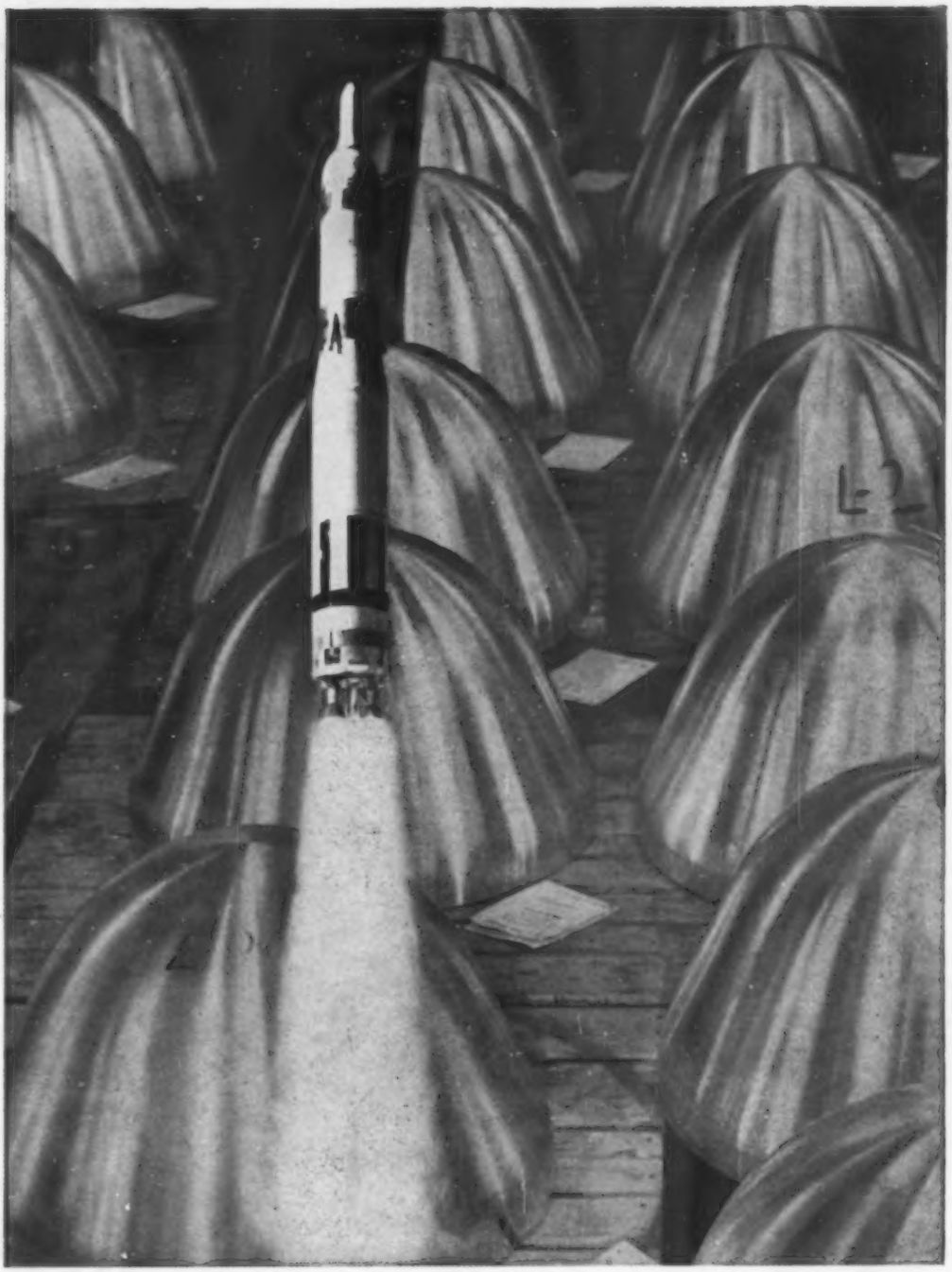
The most effective implementation of such a scheme demands that the computer be digital in nature. For compatibility, the output signals from the gyros, and from the accelerometers as well, should also be digital in nature.

Existing gyros can be used in digital modes of operation with only slight modification in their precession axis components (torquer and takeoff). For example, pulse torquing is a method in which the torquer signals provided to the gyro are in the form of discrete pulses of energy rather than a continuous analog current. Since it is an amount of energy which is introduced, summing the number of torque pulses is equivalent to integrating a sustained current. Since the torquer scale factor, is known, direct digital exchange of information between the computer and gyro becomes possible.

The present difficulties of such a scheme are threefold. First is the problem of devising the necessary electronics to generate a train of pulses with the assurance that each pulse contains exactly the same amount of energy. Second, the gyro must be designed so that its transient response is compatible with the input pulse, and the gyro torquer must be designed so as not to overly distort the input. The third area of difficulty is obtaining basic sensors with dynamic ranges sufficiently wide to utilize the computer's capability.

Body-mounted gyros require greater angular freedom of movement about their precession axis than comparable conventional gyros. Wide-angle, fluid-floated gyroscopes are now being built by Minneapolis-Honeywell, Kearfott, and Nortronics.

The Air Force is funding development of the AJN-7 system by the Ford Instrument Company; this is a feasibility model of a gimballess platform. Several other firms, including those mentioned above, are following this approach with their own funds. Its use



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Rate Gyroscopes

General Performance Specifications

SUBMINIATURE

GENERAL

Maximum Angular Rate
0.1 rad/sec to 10 rad/sec

Undamped Natural Frequency
15 cps to 80 cps
(Actual measurements)

Threshold and Resolution
0.03% of maximum rate

Friction and Hysteresis at Null
Less than 0.10% of maximum rate

Linearity
½% of maximum rate plus ¼% of reading rate

Damping Ratio
0.2 to 2.0 critical (room temperature)
Variation (between -55°C and 80°C) is 0.4 total
(Frequency response measurements)

AMBIENT CONDITIONS

Temperature
-55°C to 80°C (Standard)
(Up to 150°C on request)

Vibration
50 G up to 2000 cps

Shock
100 G along any axis

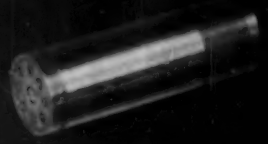
MOTOR

Excitation
26 V ± 10%, 400 cps, 3—phase
26 V ± 10%, 400 cps, 2—phase

TRANSDUCER

Signal-To-Noise Ratio
1,000:1 (Minimum)
(Based on maximum rate)

Zero Calibration
0.01 to 0.2% of maximum rate
(Depending on overall requirements)



SIZE: 15/16" DIA. x 2-1/2"

MINIATURE

GENERAL

Maximum Angular Rate
0.05 rad/sec to 10 rad/sec

Undamped Natural Frequency
8 cps to 80 cps
(Actual measurements)

Threshold and Resolution
0.03% of maximum rate

Friction and Hysteresis at Null
Less than 0.20% of maximum rate

Linearity
½% of maximum rate plus ¼% of reading rate

Damping Ratio
0.2 to 2.0 critical (room temperature)
Variation (between -55°C and 80°C) is 0.4 total
(Frequency response measurements)

AMBIENT CONDITIONS

Temperature
-55°C to 80°C (Standard)
(Up to 150°C on request)

Vibration 20 G up to 2000 cps

Shock 100 G along any axis

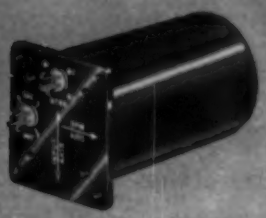
MOTOR

Excitation
115 V ± 10%, 400 cps, 3—, 2—phase
26 V ± 10%, 400 cps, 3—, 2—phase

TRANSDUCER

Signal-To-Noise Ratio
1,000:1 (Minimum)
(Based on maximum rate)

Zero Calibration
0.01 to 0.2% of maximum rate
(Depending on overall requirements)



SIZE: 1¾" DIA. x 3⅛"

D. C.

GENERAL

Maximum Angular Rate
6°/sec minimum

Undamped Natural Frequency
2.5 cps at maximum rate

Threshold and Resolution
0.5% of maximum rate

Friction and Hysteresis at Null
Less than 1% of maximum rate

Linearity
5% of maximum rate

Damping Ratio — Air Damped
1.0 to 4.0 critical (room temperature)

Output at Maximum Rate
4 ma with 500 ohm load
(Optional output potentiometer available)

AMBIENT CONDITIONS

Life
1500 hours minimum

Temperature
65°F to 165°F

Vibrations
5 G up to 2000 cps

Shock
25 G along any axis

MOTOR

Excitation
28 VDC (Standard)
14 VDC (On request)

SIZE: 2.271" DIA. x 4.667"

SUBMINIATURE INVERTER-DEMODULATOR

GENERAL

Maximum Angular Rate
0.1 rad/sec to 10 rad/sec

Undamped Natural Frequency
15 cps to 80 cps

Threshold and Resolution
0.03% of maximum rate

Friction and Hysteresis at Null
Less than 0.10% of maximum rate

Linearity
½% of maximum rate plus ½% of reading rate

Damping Ratio
0.2 to 2.0 critical (room temperature) Variation (between -55°C and 80°C) is 0.4 total (Frequency response measurements)

AMBIENT CONDITIONS

Temperature
-55°C to 90°C

Vibration
50 G up to 2000 cps

Shock
100 G along any axis

MOTOR

Excitation
± 3 VDC (internally inverted to drive a hysteresis motor)

TRANSDUCER

Signal-To-Noise Ratio
1,000:1 (Minimum)
(Based on maximum rate)

Zero Calibration
0.2% of maximum rate or less
(Depending on overall requirements)

SIZE: 1-1/2" DIA. x 3⅛"

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AIRCRAFT INSTRUMENT DIVISION

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in future years appears very probable.

The basic limiting threshold for a high-accuracy gyro depends on the residual torques caused by the suspension. To many investigators, improving the suspension appears to be the way to improve gyros.

The University of Illinois, General Electric, and Minneapolis-Honeywell are developing gyros which use electrostatic forces to suspend the rotor. Other firms have dropped their endeavors in this field.

A basic problem, in addition to the high voltages and low vacuum usually required, is the difficulty of obtaining the high accuracy, close tolerance, and homogeneous elements required for the rotor and suspension system.

The Air Force is seeking means to obtain spheres with tolerances beyond the current state of the art.

General Electric and Kearfott are both developing cryogenic gyros. This type is in essence a device using a magnetic suspension in which the performance of the magnetic circuitry is dependent upon superconductivity phenomena. Both electrostatic and cryogenic gyros are still predicted on the use of the spinning rotor.

In an attempt to eliminate the problems inherent in a spinning rotor, efforts are being made to develop gyroscopic devices which depend on the gyroscopic properties of molecules and atoms. Most of these schemes are foundering for lack of a practical scheme of detecting the output signal. In many cases, the associated electronic detection circuitry is so complex as to negate the simplicity of the basic sensor.

At present it does not appear that molecular gyros will become operational within this decade.

One thing should be clear from the preceding comments: the field of gyroscopes is anything but static. There is a great deal of ferment in ideas and great deal of competition between firms. There may even be some doubt as to whether the market is able to support so many competitors. However, any elimination is most likely to be on the basis of inability to develop new ideas.

There is always a market for a better gyro. ⠿

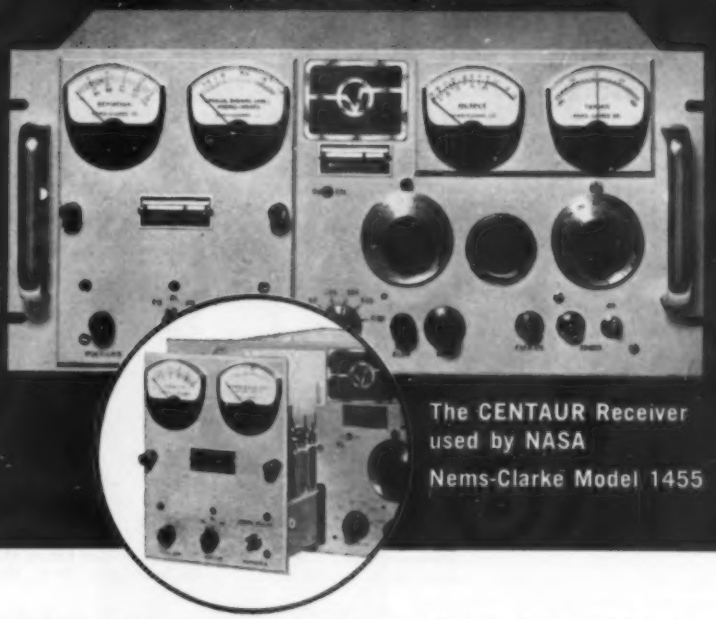
Market Outlook

(Continued from page 20)

drift errors; better understanding of physical properties of materials for achieving improved performance in varied environments; lack of long-term stability in many critical materials experienced during transport or extended storage.

–Electronic hardware. Connectors and intermodule connections are still

MODULAR TELEMETRY RECEIVER FEATURES MULTIPLE BANDWIDTH SELECTION



The CENTAUR Receiver used by NASA

Nems-Clarke Model 1455

Designed to provide a selectable bandwidth capability for PCM, the 1455 most nearly approximates a "universal" telemetry receiver. IF/Demodulator Modules are available in bandwidths ranging from 100 KC to 1.5 MC. Each module contains 3 independent demodulators. Selectable by a front panel switch, they are: Foster-Seeley Discriminator, Phase-Lock Detector, and AM envelope detector. As a further refinement in signal-to-noise ratio enhancement, the video amplifier incorporates a video bandwidth filter having a 6 db per octave roll-off adjustable from 20 KC to 1.2 MC by means of a front panel switch. This receiver is capable of **optimum** reception of any known type of telemetry signal. Features: 5 MC pre-detection recording output, playback input terminals, and integral VFO, automatically actuated by a micro-switch on the crystal socket. The modulation sensitivity and deviation meter scales provide output voltages and meter deflections which are essentially the same percentage of bandwidth in all modules.

Available as an accessory unit is the Nems-Clarke IFC 1400 Pre-Detection Converter which permits use of the 1455 with stationary-head instrumentation tape recorders for pre-detection recording.

See the 1455 Receiver at the I.R.E. Show, Booths 3917-3919.

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TONNAGE PRODUCTION OF
PENTABORANE AT CALLERY

Workmen check bulk containers of pentaborane before shipment to Air Force from Callery's Muskogee, Okla., plant

Pentaborane, like most of the other highly reactive chemicals in propulsion systems, takes respectful handling by properly supervised and trained workers. The recent start-up of tonnage production and shipment of pentaborane under Callery's Air Force contract is one indication of how well handling details have been worked out.

Another sign of pentaborane's coming of age is the issuance of safety and handling data sheets for the product by Manufacturing Chemists' Association and National Safety Council.

Callery has been able to bring the tremendous potential of the boranes to the propulsion foreground through the use of sound design and construction principles and thorough training of workers in safe handling techniques.

Write Callery for specific details on how your facility can investigate the new levels of energy available through the boranes. As the originators of boron fuels — from test tube to tonnage production — we can guide you in their chemistry, behavior and proper handling.

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being blamed as the most unreliable single class of components; need small. sensitive target trackers (optical, IR, radar) for objects of very small cross-sectional area; components advances in general lag system advances by a considerable margin—need more product improvement money as well as research funds; better methods for cooling and more R&D for cooling of solid state systems.

–Systems. Better control of aerodynamically unstable missile frames as they pass through jet stream (problem here is presence of liquid-sloshing and body-bending resonances at frequencies near the control frequencies); control problems due to aerodynamic and transducer crosstalk in aerodynamically controlled missiles; sealing and pressurization techniques need considerable improvement.

What will be the solution to all these problems—besides hard work? A Boeing spokesman feels there is one glaring answer to the reliability problem in complex G & C systems. Simplification of equipment, he said, is the most obvious and effective approach, but engineers must be willing to accept some sacrifice in performance.

An Autonetics official may have come closer to the heart of it all when he said: "It is true that we have major technical problems to overcome, but one area consistantly overlooked is the 'people' problem associated with the development of complex electro-mechanical equipment. The customer and the contractor must learn to resist oversophistication and to reduce systems to an absolute minimum. This will result in optimum mechanization for specific operational requirements." ⁂

Mini-Weld Technique

(Continued from page 27)

matrix wire to a component lead sticking through a similar hole in the Mylar. The films are coded to show the weld points, component leads and matrix wire materials.

Matrix wiring is used rather than the more common point-to-point nickel ribbon connections for several reasons. First, the matrix is a testable subassembly, somewhat similar to an etched circuit board, since the circuit is welded together on the Mylar film and only needs the correct placement of the components to complete the assembly. Secondly, the large number of cross-overs provides ease of engineering layout and often makes it possible to lay out complicated wiring patterns in one matrix rather than in two or three point-to-point layers. This is desirable because all the matrix and component

welds are accessible during final test and are not covered by a layer of insulating Mylar.

A third advantage of the matrix technique is the ease with which design constraints may be established to speed the layout process. A fourth advantage is the ease with which different materials may be used within one assembly to insure the compatibility of materials to be welded.

After final testing of a finished circuit, the entire unit is encapsulated, using precision molds, in a fire-resistant, glass-filled epoxy casting resin. The encapsulant provides a protective surrounding for the electronic circuits, and creates a reinforced structural block to withstand the rigors of military environments.

• **Wiring modules**—The wiring module, used to interconnect the circuit units, is a condensed version of the conventional back-panel wiring or cabling harness used with every electronic system.

The same basic matrix scheme used in the circuit modules is the basis of the wiring module matrix. In this case, all the electrical connections are made between pins in the wiring module, rather than between components and output pins. Due to the large number of pins involved, which may be as high as 3600, multiple layers of matrices must be used. As many as 25 layers have been used to interconnect all the pins in the *Polaris* wiring module.

The wiring module matrices are the only units custom-built for each system. Each is tailored to accommodate different locations for various types of circuit modules and the difference in number and types of modules. The outside physical appearance of all wiring modules is the same, differing only in the number of circuit modules that they will interconnect.

The ribbon matrix method of back-panel wiring is the core of the wiring module. Several of these matrix layers stacked one above the other contain all the intermodule signal and power connections required by the system.

A wiring module matrix is composed of a photosensitive film (usually 0.004-in. Mylar or cronaflex) imprinted with lines that the signal conductors will overlay and other information necessary for its fabrication. The conductors on either side of the film are welded to each other as required through holes pre-punched in the film.

The films are exactly reproduced from original drawings upon which the logic interconnections were laid out. Practically all of the information necessary for the fabrication of the matrix is then reproduced on the film. Mylar or cronaflex is used for its excellent

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new **career opportunities** for **engineers** and **physicists**

Guided Missiles Range Division of Pan American World Airways has prime responsibility for operation and maintenance of the 10,000-mile Atlantic Missile Range extending from Cape Canaveral into the Indian Ocean. Guided Missiles Range Division's dynamic growth has created new opportunities for Electronic Engineers, Systems Engineers and Physicists with degrees and experience in several fields. If you are qualified and desire to play an intimate, vital role in the nation's major missile test and astronautical explorations, we invite you to inquire about these career opportunities. You will discover that the Florida way of life offers you and your family modern living in an unparalleled vacation setting of sunshine and seashores; and that association with Guided Missiles Range Division offers beyond normal employee benefits, a 90% world-wide air-travel discount. Please address your resume in confidence to: Dr. Gilbert S. Blevins, Dept. B-37 Guided Missiles Range Division, Pan American World Airways, Inc., Patrick Air Force Base, Florida.

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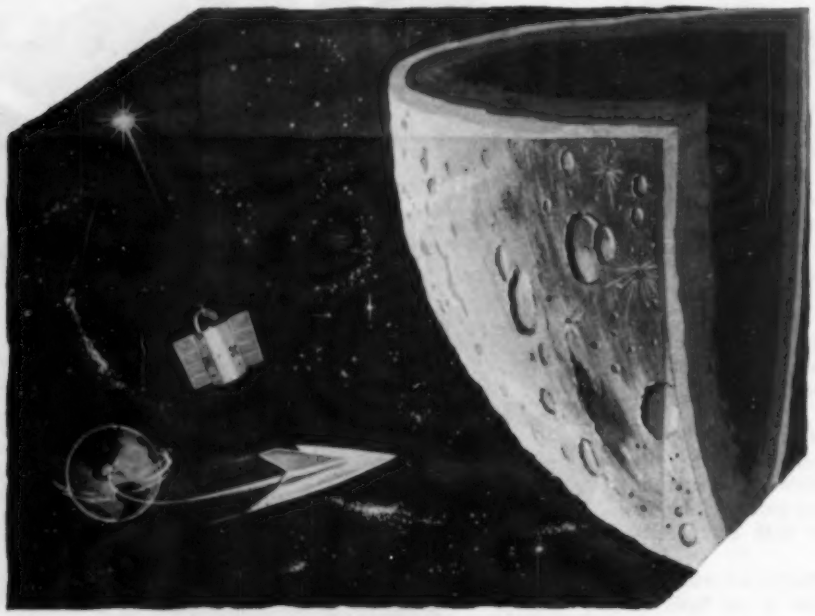
PATRICK AIR FORCE BASE, FLORIDA

Scientists and Engineers for Major Discovery Effort



. . . SPACE FLIGHT

In our continuing drive to improve the art of Space Technology long range objectives, plus definite determinations of values and priorities in terms of national and world-wide aims, are giving added impetus to the work of the Space Sciences Staff at Grumman.

The problems are many, as each experiment in space is characterized by a high degree of attention to individual design and assembly . . . seldom, if ever, would any two probes be identical. The possibility of technological surprise must also be considered in view of the limited knowledge of space as a medium of transit.

The NASA selection of Grumman as Systems Manager to develop the Orbiting Astronomical Observatory Satellite, serves to illustrate our "in house" capability for systems analysis and design of various satellites and space systems.

The Orbiting Astronomical Observatory Satellite and other advance space projects now under study by our Space Sciences Staff have created immediate openings for engineers and scientists with the following experience.

Astronomer. Senior position is available to those interested in the problems of astronomical investigations with the use of orbiting laboratories and lunar exploratory vehicles. Minimum requirements are an advanced degree and several years of pertinent experience.

Scientific Instrumentation. Scientist-engineers are required to develop scientific instrumentation systems for space and lunar environments. These programs incorporate design, development and environmental testing of space instrumentation systems. A strong background of education and experience in scientific instrumentation is required.

Space Dynamicist. MS in Applied Mechanics or Applied Math and 4 or more years' experience in the analysis of flight dynamics with at least 2 years' experience in celestial mechanics. To investigate problems associated with cislunar flight, re-entry dynamics and orbital transfer.

Thermodynamicist. Advanced degree with a minimum of 5 years' experience performing difficult heat transfer analysis. Work includes aerodynamic and re-entry heating, structural temperature determination and heat transfer phenomena in propulsion systems.

Data Processing Engineers. Background in digital data processing, logic circuit design, memory devices, R-F modulation techniques and related digital techniques required. Opportunity to participate in advanced design of systems concepts and hardware development. BSEE or BS in Physics with a minimum of 3 years' applicable experience is required.

Digital Circuits Engineer. Experience in logical design and transistor pulse circuit design for work on complex digital data systems. BSEE or BS in Physics with a minimum of 3 years' applicable experience is required.

Communications Systems Engineers. Electronic Engineers with thorough knowledge of communications techniques who wish to extend their technical background to new challenging areas. Should possess a complete understanding of AM, FM, PM and single sideband modulation processes and their application, and be willing to apply this knowledge to the latest data handling techniques. An important phase of this effort will be extensive laboratory development programs in our new Avionics Systems Center using the finest of equipment. BSEE with a minimum of 3 years' experience required.

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Bethpage, Long Island, N.Y.

insulating qualities, high tensile strength, extreme resistance to tearing and, above all, its dimensional stability even at extreme temperatures. The conductors are usually nickel ribbon, nickel wire, nickel-clad copper, or combinations of these.

Between matrix layers is a blank film which insulates one wiring layer from another.

The module is encapsulated with a flame-resistant epoxy resin under a high vacuum to eliminate the possibility of air bubbles which might impair reliability.

The encapsulated wiring module has rows and columns of symetrically spaced rectangular holes. Three of every four holes are identical and have wire-wrap terminals along one edge. Internally, the terminals are welded to matrices and signal or power circuits. Externally, the terminals eventually are wire-wrapped to circuit module terminal pins that protrude through the holes in the wiring module.

• **Wire-wrapping**—To add to the reliability of the MiniWeld system, conventional connectors—a major source of trouble in modular electronic systems—are eliminated by the use of wire-wrap connections.

The split wire-wrap terminal was developed to meet the need for a connection method possessing high reliability and allowing 25 to 50 disconnections within the life of the unit. This terminal is a variation of the original Bell Telephone Laboratories' wire-wrap terminal.

Since the split terminal uses the wrapping wire only as a means of binding the two half terminals together, the main objection to the original technique is eliminated, since the solid copper wire is cut off and does not lead to another terminal. Therefore, the problem of fatigue and breakage of the solid wire is not a problem.

These terminals have recently passed tests of 8 g's of vibration in working assemblies and 30 g's of vibration in dummy units with no detectable difficulties. The dummy units were also subjected to 100 g shock in three axes without any physical damage. The working units have been subjected to a full range of the standard environmental tests as well—including humidity, high and low temperature—after one wrap and after 20 rewraps on each terminal.

Both semiautomatic and manual tools for making the wire wrap connections and a special unwrapping tool are available commercially. In an emergency, field repairs can be made without any tools by hand-wrapping the terminals with a piece of copper wire and soldering in place. The terminals can also be welded together if desired.

This technique gives a gas-tight connection, with high inherent reliability, stemming from the fact that the soft copper wire is physically deformed, when wrapped around the sharp corners of the hard, gold-plated terminals. Multiple conductive paths are also created between the two half-terminals.

The use of wire-wrap terminals has two other unique features. Every terminal of the system is accessible for probing and testing. Also, by unwrapping one element and inserting an insulating material between the terminals, a circuit connection can be isolated from the system for testing or probing without physical removal of the circuit module.

• **Interframe cabling**—Connections between frames and to input-output and power cables is provided by Mini-Cable modules. As many of these modules as are required by the system are connected into the wiring module. The cable modules are wire-wrapped into the wiring module in the same manner as other circuit modules. The wiring module matrices then perform the function of bringing the cable connections to the correct circuit module.

For inter-frame cabling, two dummy circuit modules are used with one at each end of the cable and each wire-wrapped in a different wiring module. The cable used is a flat flexible encapsulated-copper ribbon cable, such as Flexprint.

• **Mechanical assembly**—In a Mini-Weld system package, the circuit and wiring modules are used as the prime structure; their inherent compressive strength is one of the leading design factors.

The basic erector-set structure consists of only one piece of aluminum, a web 0.190 in. thick, about which the circuit modules are clamped. Holes in the circuit modules allow insertion of a clamping bolt. A total assembly consists of five elements on each side of the web, with clamping pads at their extremities.

The clamping bolt, with special hardware, is inserted and then loaded to a value of approximately 400 lbs. This load is transmitted from the clamping pads into the circuit modules and results in a homogeneous post-loaded beam, the main support point being the web in the middle of the circuit module stack. The clamping pad design prevents any air leakage or rattling and allows the circuit module beams to expand and contract axially.

The bulk of the load is delivered to an intermediate web, which transmits the load to a fitting. The fitting, in turn, delivers the load from the intermediate web to the vehicle. To transmit the load from the center and intermediate webs to this fitting,

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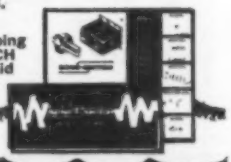

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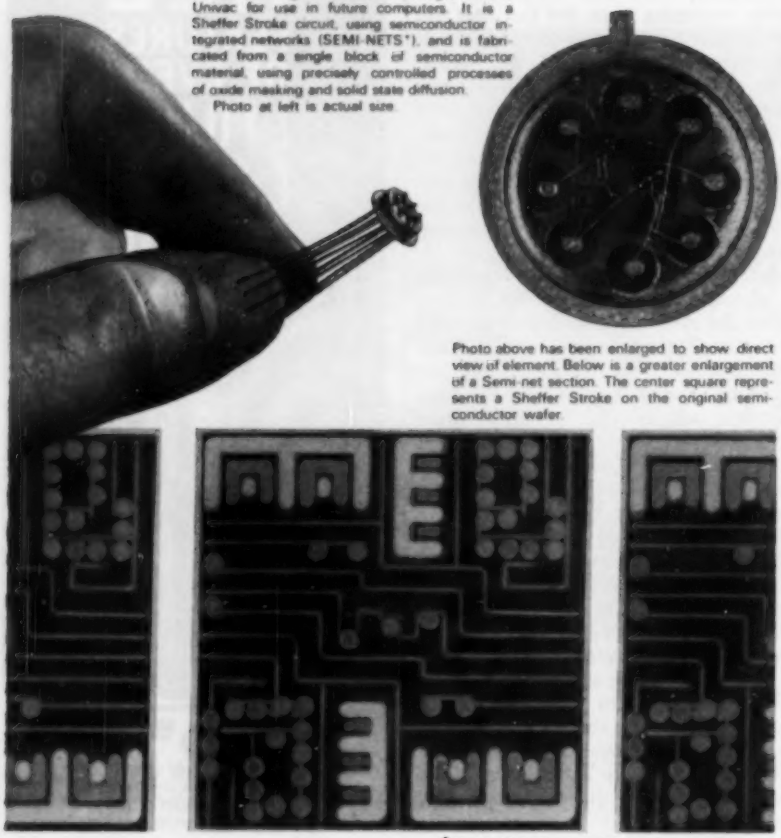

Developed by the Sperry Semiconductor Division, Norwalk, Connecticut, this logical element is currently being utilized at Remington Rand Univac for use in future computers. It is a Sheffer Stroke circuit, using semiconductor integrated networks (SEMI-NETS*), and is fabricated from a single block of semiconductor material, using precisely controlled processes of oxide masking and solid state diffusion.

Photo at left is actual size.

Photo above has been enlarged to show direct view of element. Below is a greater enlargement of a Semi-net section. The center square represents a Sheffer Stroke on the original semiconductor wafer.

* *Trade Mark, Sperry Rand Corporation*

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modular extruded sections are placed between each of the webs. Compression bolts are also passed through the extruded side frames of the system, much as the bolt is passed through the circuit module beams. The side frame assembly, therefore, becomes another postloaded structure.

The wiring module is placed on top of the webs and fastened with screws. The screws hold the module mainly for assembly purposes, because the many wire-wrap terminals to the circuit module beams hold it with an even distribution of tension.

Postloading the circuit module beams accomplishes another purpose by clamping the heat exchangers firmly between each module. The high compressive force between modules keeps to a minimum the thermal losses due to the interface between the circuit module and the heat exchanger.

Modularity of the machine is obtained by adding extruded side-frame pieces until the desired length is obtained, or by varying the length of the various webs in increments of circuit module width until the desired width of the machine is designed. Because of environmental considerations and limitations in fabricating the wiring module, the maximum size of any one frame machine has been set at 200 circuit modules.

In stacking the machines one on top of the other, each frame is completely independent of the next, since the total loads are ultimately transferred to four hold-down bolts. The only variable, therefore, is the size of the hold-down bolts, which is a function of the number of frames and the size of each frame.

• **Cooling**—The MiniWeld system is designed to meet the most rigorous thermal environments attainable with germanium transistors. Large systems may be assembled with forced convection cooling that will maintain maximum transistor case temperatures within 8°C of ambient. Forced air may be supplied by a self-contained fan assembly in the base of the system package or by the vehicle supply. Free convection may be used in ground-based systems. Forced liquid cooling may also be used in special applications.

Heat from the surface of the circuit modules is conducted to the final heat sink or heat exchanger by means of aluminum foils clamped between the modules by the bolt that holds groups of modules together. These foils carry the heat to cold plates located between rows of circuit modules if a forced air or liquid cooling technique is used.

When a heat sink is used, the foils may be tied to conductive plates that are in turn clamped to the heat sink. ##

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Litton's LN-3 Inertial Navigation System for the NATO F-104, now in production, owes its excellent performance to Litton-designed technical features such as:

Integrators with linearity of better than 1 part in 10,000.

Fully transistorized d.c. amplifiers with internal gain better than 10^7 with offsets, referred to the input, of 20 microvolts maximum. Operational characteristics are constant between —55°C. and 85°C.

The next generation of inertial systems will require engineers with experience applicable to the improvement of computer performance and the performance of other system units such as miniature inertial platforms. If you have experience in fire control, analog, servo, or gyro systems, you may find unusual satisfaction in applying your talents to the development of fresh concepts in inertial systems.

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GUIDANCE & CONTROL SYSTEMS DIVISION
Beverly Hills, California

John Tamura and Robert Ebner discuss the optimization of the LN-3 Computer Integrator design with Dr. Harold Bell, assistant director of the Guidance Systems Laboratory

"Delivery room" for a guidance system

Guidance systems and components for some of this country's most advanced ballistic missiles are being born in this room—and no hospital delivery room was ever kept freer from dust and dirt.

It's the "ultra-clean room" at Sperry Farragut—the cleanest of more than 5000 square feet of temperature-controlled clean-room facilities here. Its air locks and dust filters remove from the air all particles larger than 0.3 micron (12 millionths of an inch) and would stop cold the 3-5 micron bacteria dreaded in hospitals. Final assembly of guidance units for the MERCURY and SATURN missiles is carried out here—as well as assembly of a variety of other complex, precision mechanical and electro-mechanical equipment.

This clean room, probably the most advanced in the country in design and construction, is just one example of the ultra-modern facilities for precision military production at Sperry Farragut's 175,000 square-foot Bristol, Tennessee plant. These facilities are manned by a staff with outstanding technical competence and backed by the virtually unlimited capabilities of the Sperry Rand organization.

Our liaison engineers will welcome an opportunity to discuss application of Sperry Farragut facilities and capabilities to your requirements. o.2

Capabilities and facilities for study, design, evaluation, prototype construction, and final quantity production of precision systems, subsystems, and components for:

- *Missile guidance and control*
- *Fire control*
- *Aircraft instrumentation*
- *Navigation—land, air and sea*
- *Computers*
- *Trail marking equipment*

SPERRY FARRAGUT COMPANY

DIVISION OF SPERRY RAND CORPORATION
BRISTOL, TENNESSEE

Circle No. 17 on Subscriber Service Card.

Command Guidance

(Continued from page 28)

any momentary loss of signals or other interruptions, the range error can be corrected easily. A technique has been developed to periodically recalibrate range, using the second signal link between ground and missile.

By means of the controls placed upon the two signals, both in the air and on the ground, the reception of only one of the signals would enable the ground to reproduce exactly the second received signal. This reproduction technique allows the range scheme to handle the case of a moving missile.

With a system such as this, we can expect that the missile trajectory will be measured to within 6 inches in range, 3 microradians in angular position, 0.02 feet per second in velocity, and 20 millimicroradians per second in angular velocity. A virtue of this measurement system is that it is independent of absolute range, since these measurement accuracies are constant for any mission. With such accuracies guidance-system errors become insignificant.

• **Hardening possibilities**—At this point, the accuracy of delivery of a payload to target becomes a function of the known position of the target and the aberrations in the re-entry path of the nose cone of the missile. Since this system is not dependent upon the super-precise positioning of a large tracking antenna, it becomes relatively easy to harden the entire guidance site.

Not long ago there was much talk of the thermonuclear warhead being the "final" weapon and leaving "total destruction in its wake." We now know this to be false, and it is possible, with current techniques to build hardened ground sites that will withstand the ravages of a 10-megaton burst a very short distance away.

Launch and guidance complexes can hand over control to an undamaged site if a ground system should be knocked out. Additionally, by staggering launch times, it is possible for one site to control several missiles in flight at once. Thus it is possible to build guidance and launch complexes that can take even direct hits and continue to perform their missions.

Because the guidance computer remains on the ground, it can be made versatile and flexible. This allows storage of almost immediately available data on a large number of targets. Thus any missile can be fired at any target at essentially any time. (Range limitations, of course, must be considered.)

In addition, the ground-based equipment, including the computer, will be greatly simplified. The point has been reached already where only one guidance control officer actually takes part in a countdown.

• **As for jamming**—In the past, the great hue and cry about radio guidance systems has been that of alleged vulnerability to jamming. This argument is not valid, however, since with secure transmission techniques the guidance system can have "orders of magnitude" more effective power than the best and "most intelligent" jammers.

The task of jamming the system is immense considering the effective power advantage, plus the following reaction time requirements:

(1) Discover a missile is being guided

(2) Determine the frequencies being used

(3) Unravel the encoding scheme used

(4) Determine in which direction the missile antenna is "looking"

(5) Move about to get within the beam of the missile antenna

(6) Get on the air, on frequency before it is too late

While jamming of any radio link can never be completely ignored, it certainly is not a task for a lonely spy

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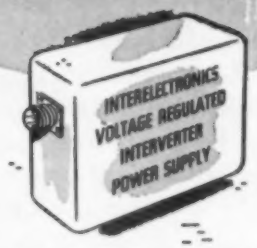
SOLID-STATE POWER INVERTERS
over 260,000 logged hours— voltage-regulated, frequency-controlled, for missile, telemeter, ground-support, 135°C all-silicon units available now—



Interelectronics all-silicon thyratron-like gating elements and cubic-grain toroidal magnetic components convert DC to any desired number of AC or DC outputs from 1 to 10,000 watts.

Ultra-reliable in operation (over 260,000 logged hours), no moving parts, unharmed by shorting output or reversing input polarity. Wide input range (18 to 32 volts DC), high conversion efficiency (to 92%, including voltage regulation by Interelectronics patented reflex high-efficiency magnetic amplifier circuitry).

Light weight (to 6 watts/oz.), compact (to 8 watts/cu. in.), low ripple (to 0.01 mv. p-p), excellent voltage regulation (to 0.1%), precise frequency control (to 0.2% with Interelectronics extreme environment magnetostrictive standards or to 0.0001% with fork or piezoelectric standards).

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AC single and polyphase units supply sine waveform output (to 2% harmonics), will deliver up to ten times rated line current into a short circuit or actuate MIL type magnetic circuit breakers or fuses, will start gyros and motors with starting current surges up to ten times normal operating line current.

Now in use in major missiles, powering telemeter transmitters, radar beacons, electronic equipment. Single and polyphase units now power airborne and marine missile gyros, synchros, servos, magnetic amplifiers.

Interelectronics—first and most experienced in the solid-state power supply field produces its own all-silicon solid-state gating elements, all high flux density magnetic components, high temperature ultra-reliable film capacitors and components, has complete facilities and know how—has designed and delivered more working KVA than any other firm!

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• **A more complete description of the Laboratory's work will be sent to you upon request.**

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with his handy-dandy suitcase jammer. In fact, it is conceivable that it would take more and larger equipment than the ground station itself, emplaced near the ground site. Military security people might have something to say about this.

• **Command link**—As has already been pointed out, a launch complex can have considerable flexibility in missile control, and while salvo, or firing all at once, is a very difficult problem, it can be closely approached.

It is possible to stagger the firing of a group of missiles and to control during the critical periods of flight. The firing rate is based, among other factors, on the precision of control during the non-radio period of guidance.

Thus, the better this control (as the autopilot approaches an inertial system), the higher the possible rate of fire since the radio guidance period becomes shorter. This has the advantage of rapid fire with another important advantage: since there can be very accurate trajectory measurement, it is possible to attain a pre-impact prediction of target damage very shortly after burn-out.

The prediction of where a given successful warhead will detonate can permit deployment of a second missile to a different target, which results in minimizing the total number of missiles required for accomplishment of a particular war plan—or, to express it another way, increasing the destructiveness of the entire missile force.

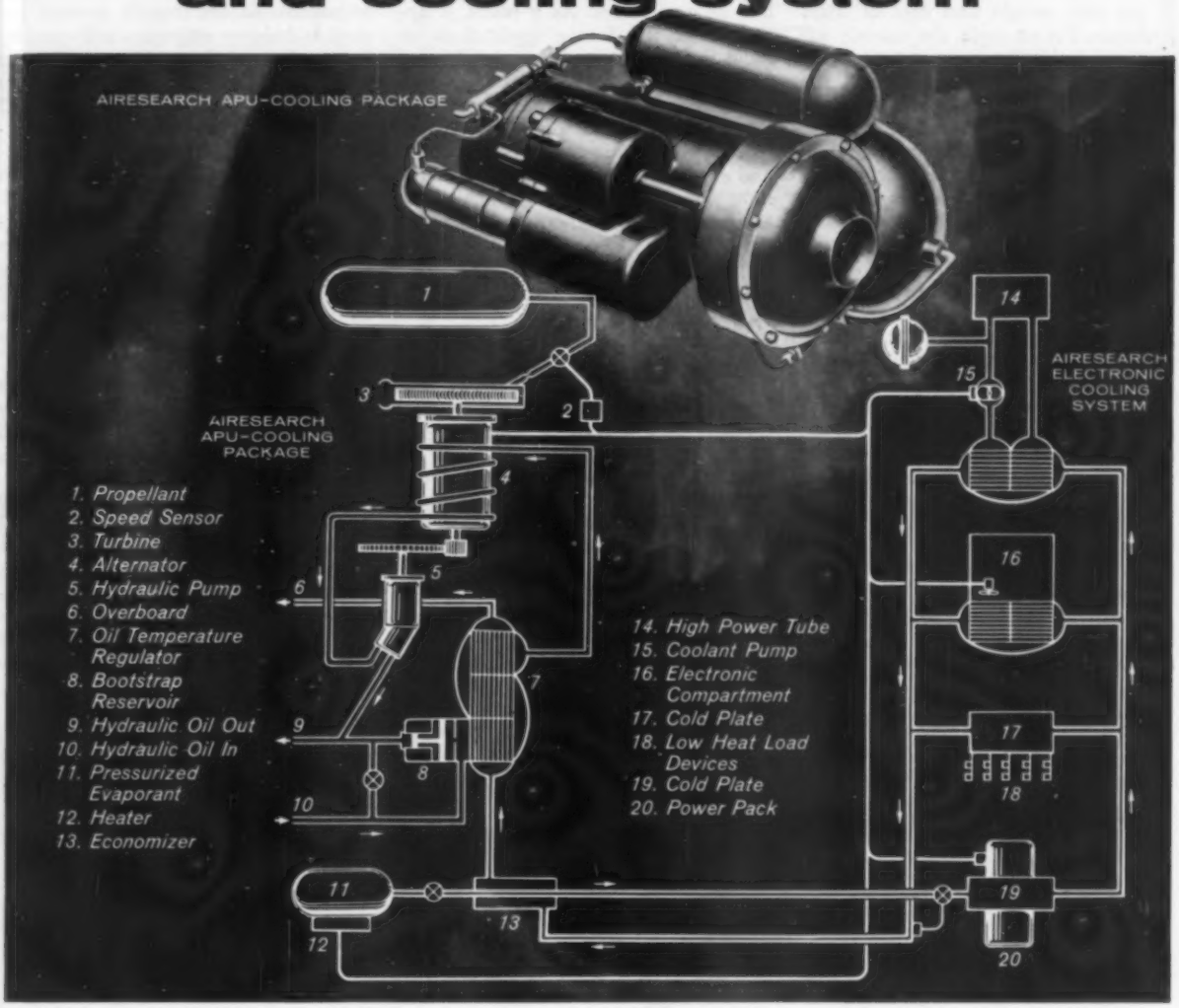
Another consequence of the command link to the missile is the ability to "recall" (or destroy) a missile in flight. Conceivably, at some point in time, the ability to recall a missile could be the most important single influence on our very existence.

The function of receiving the commands from the ground, decoding them and then acting on the commands are the only functions that need be performed by the missileborne equipment other than those of retransmitting the signals for the ground. As a result of placing all of the computation functions on the ground along with the trajectory sensing devices, the airborne portion of the system becomes quite small and of light weight.

• **Weight and cost**—Considering all the requirements of an advanced system, a typical airborne system can be packaged in the space of 180 cubic inches. The weight of such a system protected against the rugged environment of today's missiles would be a mere 12 pounds. The total power consumption for such a beacon would be as low as 80 watts.

Another result of placing the minimum of equipment in the air is the cost of the airborne package. Thus the

Integrated accessory power and cooling system



meets the most advanced missile and space vehicle requirements

AiResearch has developed a *single* system package for missiles and space vehicles to meet increasing accessory power and cooling load requirements in the face of decreasing size and weight allowances.

This integrated accessory power and cooling system supplies hydraulic power for actuating systems, 3200 or 400 cycle three-phase electric power for guidance and control, and at the same time provides cooling both for the APU and all electronic equipment operating in the missile or space vehicle.

The cooling system in the example shown here uses liquid ammonia as the expendable evaporant, and each heat load area has a separate temperature control valve. Alternator and controls, turbine assembly and APU liquid propellant fuel tank are patterned after operationally proven components.

World leader in the design and manufacture of cooling and accessory power systems, AiResearch has delivered more missile APUs than any other company, and is the leader in advanced electronic cooling systems for aircraft, missiles and spacecraft.

AiResearch design and manufacturing experience in these two fields includes: liquid and solid propellant APUs; hydraulic and hot gas actuators and control systems; 3200 and 400 cycle alternators; cold plates; expendable and closed cycle gas and liquid cooling systems; cryogenic cooling systems.

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throw-away portion of the radio guidance system today is an order of magnitude less expensive and smaller than other systems programed for the future.

As advancements in the state of the art continue there can be more saving in the size, weight and cost of these packages. For example, the recently announced "micro" transistors, manufactured by several companies, point the way to size reductions of some circuits by better than 2:1.

• **Reliability**—The reliability of the airborne equipment is also helped by the simplicity of the radio guidance beacon. With considerably less equipment operating in the severe missile environment, the probability of failure is correspondingly reduced. As an example of this, the present *Atlas* airborne radio guidance has a perfect record of never having caused the abort of a missile.

As we have pointed out, the radio guidance system offers several definite advantages for the ICBM case. As the requirements of future systems become more stringent these virtues should become more and more evident.

In the case of extraterrestrial missions, radio guidance systems offer unique solutions to otherwise "unsolvable" problems. For successful arrival at a lunar or planetary destination, the accuracy and long-term correction capability of this technique is mandatory. When the problems of trajectory measurement over long periods of drifting in space are considered, it is clearly desirable that we have a system that does not continually add and accumulate its own errors. As a result, it appears that the future applications of radio guidance systems are bright and long.

If it is desired to have today, as well as in the future, a guidance system that adds a minimum of size, weight and expense to the missile—and at the same time has the highest achievable accuracy—radio guidance is clearly indicated. ⌗

Inertial Guidance

(Continued from page 29)

by maintaining the system in continual erection and alignment with periodic calibration or realignments.

This approach, though not ideal, appears to be a practical solution for some near-future systems. Rapid warm-up from a cold start is an objective of future systems so that continual operation will not be necessary.

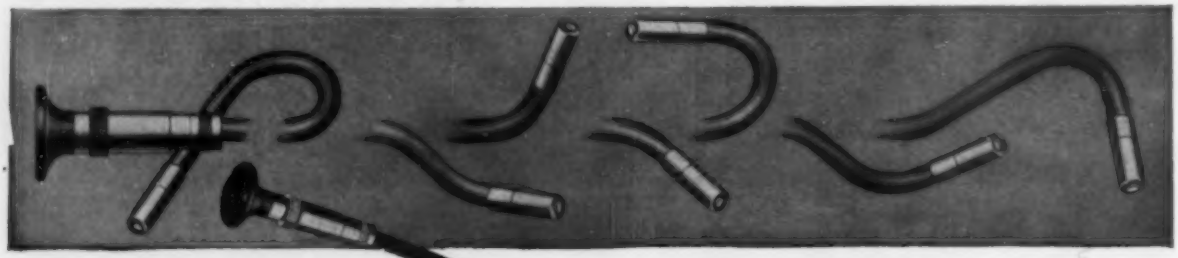
Accuracy of future inertial guidance systems probably will be limited primarily by the ability to erect, align, and calibrate them. The problem of precisely erecting the inertial guidance system to a plane perpendicular to the local gravity is even today secondary when compared with the task of obtaining initial direction for azimuth alignment. In this regard, present optical techniques impose significant operational restrictions. However, the use of improved north-seeking gyros (gyro compassing) to determine inertial azimuth will soon become commonplace.

We thus will have the ability to erect and align completely the all-inertial systems independent of any external equipment; we will need only to insert initial position coordinates. Response time will be limited chiefly by the need to warm-up and stabilize critical components and by the environmental noise.

• **Cost, development time, and size**—The same trends which tend to improve reliability also will reduce cost, development time, and size and weight.

The major cost of today's all-inertial system is in development time and in the precise electromechanical equipment and precision electronics. Both developmental and manufacturing costs decrease as knowledge of inertial techniques expands.

So also, as the inertial sensors are simplified and more of the tasks are



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shifted to the digital computer, there will be considerable reductions in cost, development time, size, and weight of the inertial guidance system. The ability of the inertial guidance system to operate in a self-contained manner and to check itself will save cost by eliminating the need for ground support equipment.

Inertial navigation and guidance has come of age. The practicality of this guidance method is accepted. The trend in the U.S. for highly accurate ICBM guidance systems has moved from radio alone, to radio with inertial as alternate, to inertial with radio backup, and finally to inertial alone. The advantages of the completely self-contained ICBM inertial guidance system apply also to other military applications from submarines, land vehicles, and aircraft to missiles, satellites, and space vehicles.

Closely related to the ICBM and of major significance is the launching of satellites and space vehicles where the inertial guidance system permits the selection of optimum trajectories. The savings in fuel will mean significant increases in overall pay load for the space vehicle.

What about future inertial guidance systems? A new line of inertial components is emerging: it will utilize air bearings, multi-axis flotation techniques, electromagnetic suspension, electrostatic suspension, or cryogenic suspension techniques. Some of these will not be operational for several years.

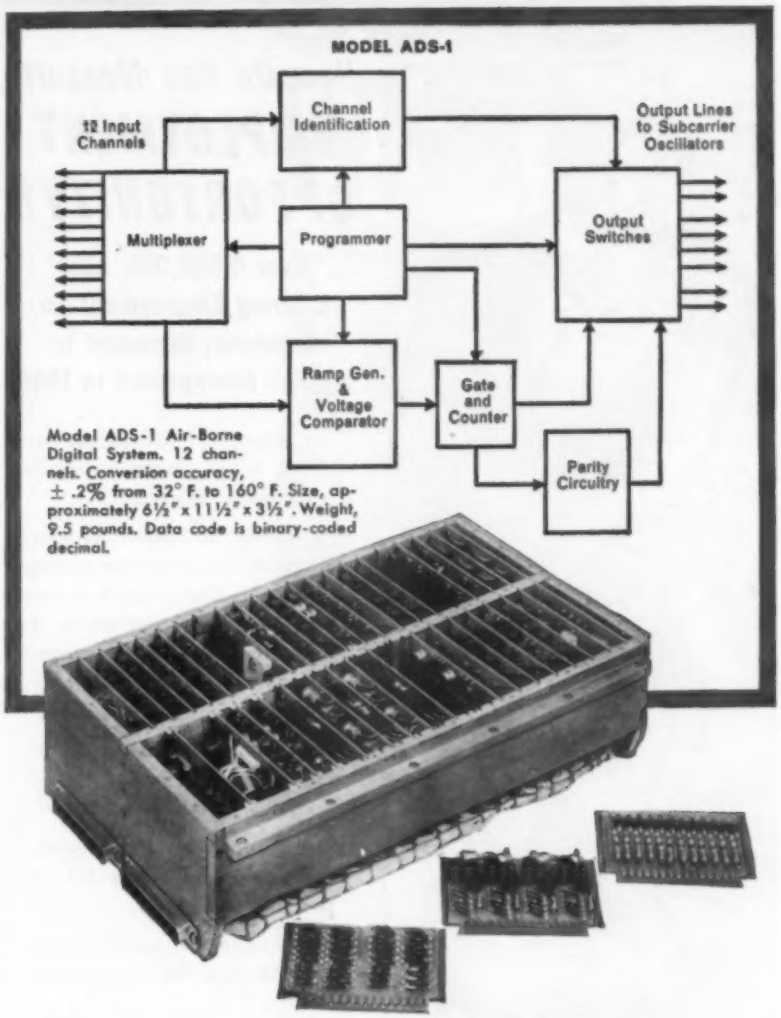
Much of the future effort will be directed toward making components more reliable and in reducing their cost, size and weight. The user of inertial guidance equipment can look forward confidently during the next 10 years to accuracies as good as he wishes.

The ultimate share of the guidance task between the radio and inertial systems will be determined largely by reliability considerations. When a man is in the spacecraft he will insist on having inertial guidance so that he will not have to depend on the idiosyncrasies of ground-based personnel or equipment.

However, he will want to have the assurance that the ground-based equipment can be used in case of an emergency. Radio guidance, then, will continue to provide a real service on applications where precise inertial equipment is not required or where the utmost in reliability for a single launching is a necessity. Such applications will include many of the space vehicle launchings during the next 10 years.

But, for secure, self-contained, accurate guidance of ICBM's with unlimited salvo capability and mission flexibility, inertial guidance must be the choice. ⌗

DIGITAL DATA SYSTEMS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Model ADS-1 Air-Borne Digital System. 12 channels. Conversion accuracy, ± .2% from 32° F. to 160° F. Size, approximately 6½" x 11½" x 3½". Weight, 9.5 pounds. Data code is binary-coded decimal.

An air-borne digital system that is small, rugged, accurate, low in cost

Typical of Curtiss-Wright digital systems is Model ADS-1, designed primarily for missile use. It converts multiplexed analog voltages to a digital equivalent for use with FM-FM Telemetry Systems, magnetic or paper tape recorders. System includes input multiplexing, an analog to digital converter, output switching, channel identification and parity checking. Composed entirely of solid state components, except for 12 electromechanical input switching relays. Ideal also for ground instrumentation, industrial quality control, development laboratories. Special systems custom-designed to meet your specific requirements. Blueprint your problem and let us suggest an answer.

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industry

Douglas Report Reveals Diversification Studies

DOUGLAS AIRCRAFT Company is studying several diversification ventures, it was disclosed in a recent stockholders report.

No further details were given, but there was some hint that the company viewed electronics as a promising field. The most recent move made by Douglas into other fields was the creation of Astropower, Inc., a subsidiary devoted to research and development in advanced propulsion systems.

Although Douglas suffered a net loss in the 1960 fiscal year, the company termed it "one of the company's most outstanding years in terms of defense business." Douglas copped several coveted military projects, including the Navy's *Missileer* aircraft, the Air Force *Skybolt* ALBM and a major contract on the Army's *Nike-Zeus* antimissile-missile.

Improvements and production continued on *Nike-Hercules, Honest John, Genie* and *Thor* missiles.

The largest single National Aeronautics and Space Administration award of the year was won by Douglas for the $68 million S-IV stage of the Saturn booster. The award called for the design, development and production of 10 of the second-stage vehicles. The S-IV will be 18 feet in diameter, about 42 feet in length and powered by four 70,000-lb.-thrust LOX-liquid hydrogen engines. Douglas plans to increase its capability in the cryogenic field with the program.

The Douglas-built *Thor* enjoyed a successful year as a space booster and prompted development on a more powerful version. The rocket was responsible for 14 of the nation's total of 16 successful satellite launchings in 1960. The company said the booster actually functioned successfully in 16 of 21 starts, but two launches failed because of malfunctions in other stages of the vehicles.

Satellites launched by *Thor* were: NASA's *Pioneer V, Tiros I, Echo I* and *Tiros II;* seven Air Force *Discoverers;* two *Transits,* sponsored by ARPA and the Navy; and *Courier 1B* sponsored by ARPA and the Army. Douglas' *Delta* served as upper stages in the *Echo* and *Tiros* shots.

Forty-eight *Thors* have already been ordered for future satellite boosting tasks. Included are additional *Discoverers* to be launched with the improved *Thor.* The *Delta* will be used in 1961 for another *Tiros* meteorological satellite and satellites designed

for deep space research, solar spectroscopy studies and radiation and atmospheric structure analysis. The company also holds a number of study contracts awarded by both the military and NASA, including one for the operations phases of the advanced *Saturn, C-2* system.

Losses in the past two years are attributed to the introduction by the company of an entirely new jet transport, the DC-8, to the market. Fourth quarter marks stayed in the black and brought the year's total to some improvement over 1959.

Net sales in 1960 were $1,174 million compared to $884 million in fiscal 1959. Net loss was $19.4 million, considerably less than the previous year's $33.8 million. The company enjoyed a fourth quarter profit of $2.4 million.

During the 1960 fiscal year Douglas trimmed its working force by about 16,000 employees—from 65,500 to 49,700 people. The cut decreased the payroll by $62 million. ⌗

General Precision Files Suit Against Martin Co.

GENERAL PRECISION Equipment Corp. has filed an anti-trust suit against The Martin Co. of Baltimore, largest shareholder with about 15% of its outstanding voting stock.

The suit cites Martin with violation of Section 7 of the Clayton Act and asks that Martin be made to divest itself of its stock, and prohibited from increasing its holdings, voting its holdings or otherwise interfering. General Precision is also asking for damages and other appropriate relief.

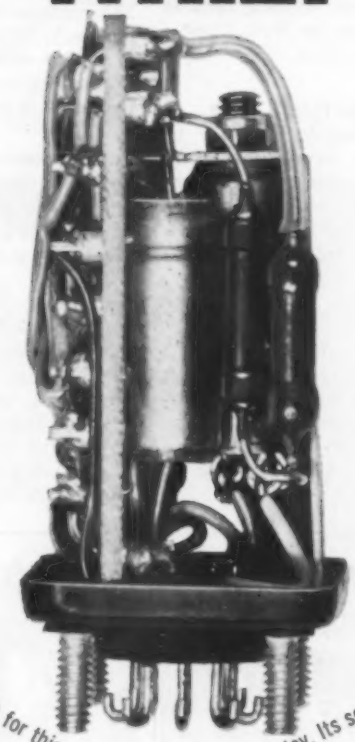
General Precision said the action was initiated after the company received a letter from The Martin Company demanding appointment of Martin's Board Chairman and General Counsel as Martin representatives on the Board. It also demanded removal of six present directors.

GPE Chairman James W. Murray noted that "Over 50% of the total business of the General Precision companies is done with competitors of the Martin Co., compared with approximately one percent with Martin . . . Any takeover of General Precision . . . can only have an adverse effect upon our business with its competitors."

Martin's sales in 1960 were more than $600 million. General Precision's sales were $244 million. ⌗

RADIO CORP. OF AMERICA, Electronic Data Processing Division has consolidated its administrative and home office personnel at company facilities in Cherry Hill, N.J. A product planning group, now at Pennsauken,

50-G WHIZ!



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THE AWH AYDON COMPANY
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N.J., will be transferred in late spring. Manufacturing and engineering activities of the Division will continue at Camden, Palm Beach Gardens, Fla., and Natick, Mass.

ELECTRIC AUTOLITE CO. will open its third wire and cable plant to supply the missile/space and electronic industries next month at El Segundo, Calif. The plant will have a capacity of 500,000 feet per day. Autolite oprates three other plants on the West Coast.

HUGHES AIRCRAFT CO. is building a 35,000-sq.-ft. addition to its headquarters to handle increasing production and development requirements. The new building will increase facilities to more than 100,000 sq. ft. near Los Angeles International Airport.

PICKARD & BURNS, INC., electronics subsidiary of Gorham Manufacturing Co. has planned construction of a 60,000-sq.-ft. R&D laboratory. The lab will occupy six acres of land in the Waltham R&D park on Massachusetts' Route 128.

financial

Telecomputing Corp.—Record sales of $48.8 million were reported for the fiscal year ended Oct. 30, an increase of 27.4% from the previous year's $38.3 million. Order backlog was at a record year-end high of $30 million, compared to $27.7 million at the end of 1959. However, the company sustained a loss for the year of $273,272, compared to net profits of $1.9 million in 1959. The loss was attributed to a $2.1 million write-off on the Air Traffic Beacon Ground System and investments in research and expansions.

Amphenol-Borg Electronics Corp.—Net sales in 1960 were $60.4 million, up 6.9% over sales of $56.5 million. Earnings were $2.934 million, up slightly from the previous year's $2.926 million.

The Gabriel Co. is planning to sell its Electronics Division, which operated at a considerable loss during the past fiscal year. No details of the plan have been disclosed.

Gabriel President John H. Briggs said the losses sustained by the Electronics Division, combined with those suffered by the Bohanan Division, gave the company its first losing year in six years. The Bohanan Division has been consolidated with Rocket Power/Talco to preclude future operating losses.

The Gabriel president pointed out that the Automotive, Rocket Power/Talco and International Divisions operated at a profit, reducing the year's total profit loss to $436,556. The company's net sales were $31.2 million, topping 1959's record of $28.8 million.

Lockheed Aircraft Corp.—A net loss of about $43 million is forecast for the company, although the last six months were profitable with net for the period estimated at $12.5 million.

International Resistance Co. has entered the rapidly-growing semiconductor field with the purchase of North American Electronics, Inc. of Lynn, Mass. The company plans to add "substantially" to facilities to meet 1962 requirements.

Astra Technical Instrument will expand its facilities at Los Angeles to concentrate on design and manufacture of temperature measurement systems and components. The company also occupies manufacturing and testing facilities in Santa Ana, Calif.

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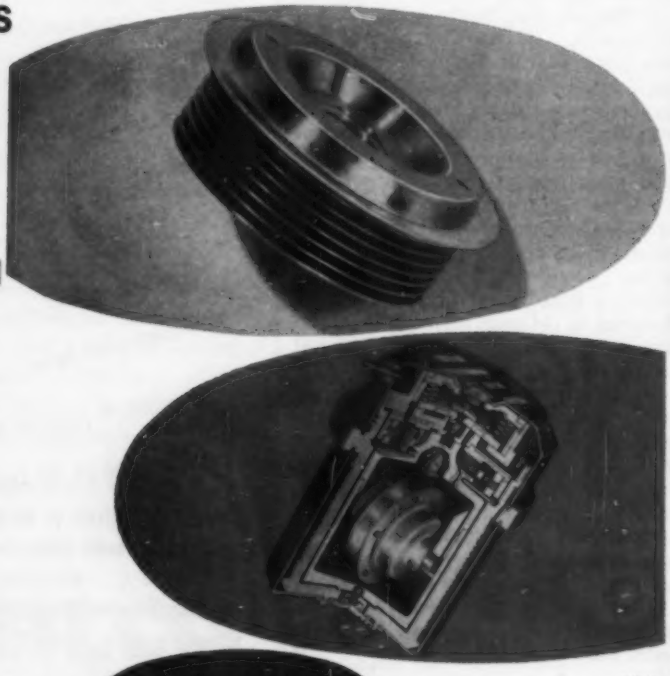

The complex new gas-bearing gyroscope shown here in a cut-away has a bell-shaped ceramic spin motor. Its interior spins at 24,000 revolutions per minute suspended on a film of helium gas only 25 millionths of an inch thick. The gyro weighs just 8 ounces, is 2.8" long and 2.0" in diameter.

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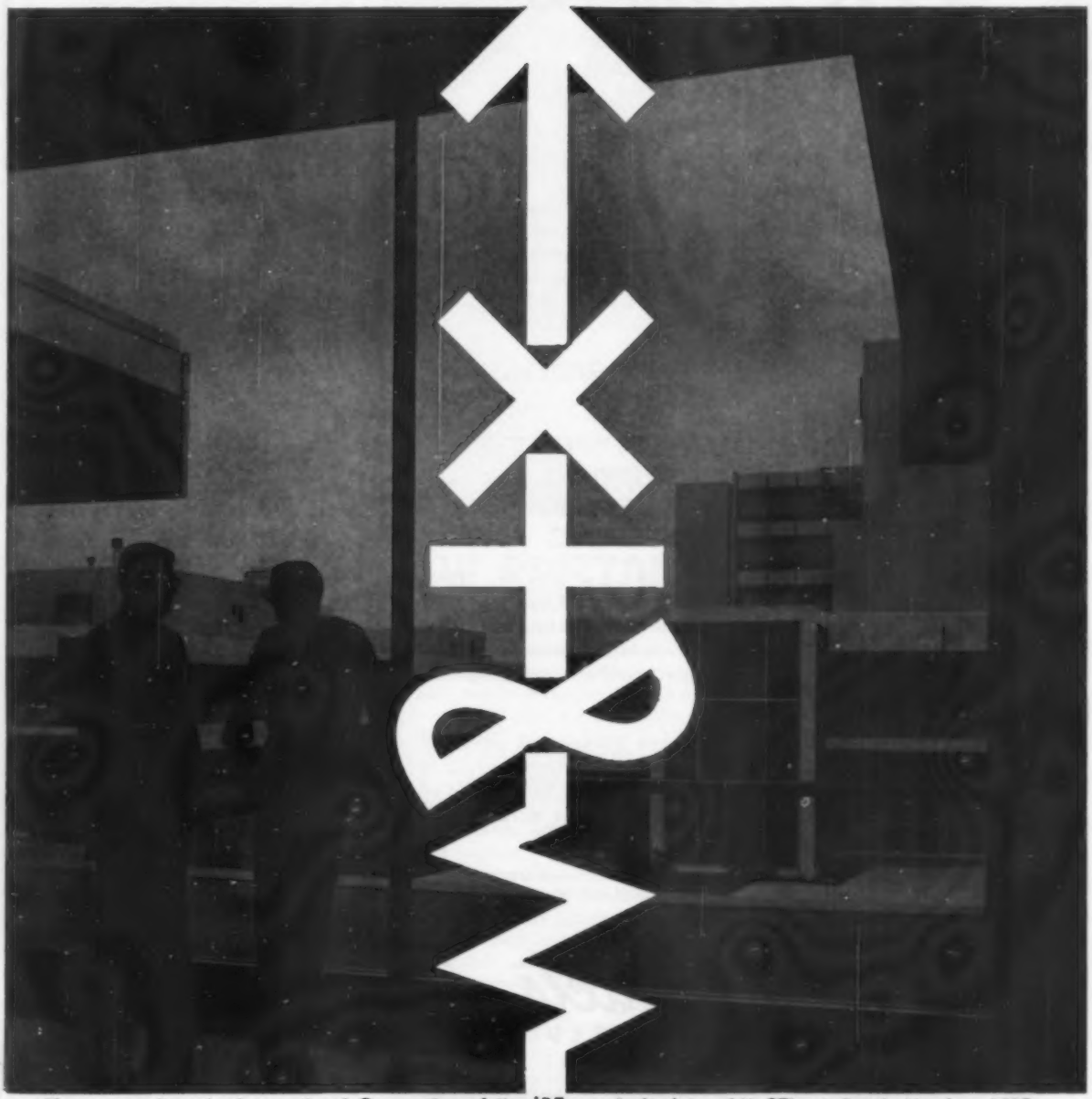

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names in the news

Dr. Victor Twersky: Head of research at the Electronic Defense Laboratories of Sylvania Electric Products, Inc., promoted to senior scientist. Internationally known for his work in the fields of electromagnetic wave scattering and propagation, he is one of three persons in the nation to achieve this position with General Telephone & Electronics Corporation, the parent organization.

Col. Francis N. Miller: Former chief of staff, U.S. Army Proving Ground, Fort Huachuca, Ariz., appointed head of field engineering section at Electronic Defense Laboratories of Sylvania Electric Products, Inc., Mountain View, Calif.

Ernest T. Andrews: Of E. T. Andrews & Co., Hartford, Conn., and **Louis G. Resnik,** senior partner in Paskus, Gordon & Hyman, New York City, elected to board of directors of Microwave Corporation of America, Stamford, Conn.

Wayne D. Stinnett: Appointed manager of newly-formed special products division of Aerojet-General's liquid-rocket plant, Sacramento, Calif., which manufactures the *Titan* ICBM propulsion system.

Dr. Sidney W. Kash: Former manager of the plasma physics department at Lockheed Missiles and Space Division, Palo Alto, Calif., appointed supervisor of the plasma and electron section in physics research at Armour Research Foundation.

Rear Adm. Thomas G. Wallace, USN-ret.: Joins the advanced development section of Admiral Corporation in Palo Alto, Calif.

Ellis G. Slack: Appointed assistant to the president of Gulton Industries, Inc., Metuchen, N.J. Former general manager of Harvard Industries' frequency standards division at Asbury Park, N.J., he also has been associated with National Electric Products in Pittsburgh and Ames Aeronautical Laboratory at Moffett Field, Calif.

Paul W. Beamer: Named manager of product and sales development of new marketing group created by Wyman-Gordon Co., Worcester, Mass., for expansion in nuclear, power generation, and electronics fields. Other appointments to this group are **Richard Benson,** product manager, gas turbine applications; **Paul J. Wisniewski,** product manager for the nuclear and electronics applications; **Martin A. Komertz, Jr.,** product manager for military sales and special products; and **Thomas U. Chace,** product manager, airframe and missile applications.

Dr. Michael J. DiToro: Joins technical staff of Cardion Electronics, Inc., Westbury, N.Y., as vice president for research. Former director of engineering at PRD Electronics, Inc., Brooklyn, has back-

ground of more than 25 years in electronics and basic sciences.

W. W. (Win) Harris: Appointed administrative manager of the Datalab Division of Consolidated Electrodynamics Corp., a subsidiary of Bell & Howell Co.

William Rympalski: Appointed general manager of Telemetal Products, Inc., a subsidiary of Polarad Electronics Corp., Long Island City. With Polarad over 12 years, was formerly chief production supervisor at Polarad and manufacturing consultant to Telemetal.

Raymond S. Fries: Named general manager of ground support division of American Electronics, Inc. For 13 years prior to joining the firm, he held various management assignments with Minneapolis-Honeywell Regulator Co.

John Manniello: Promoted from director of marketing to vice president of CBS Laboratories, Stamford, Conn.

Kerby H. Fisk: Board chairman and chief executive officer of Allied Chemical Corp., elected director of Minneapolis-Honeywell Regulator Company.

George A. Rohner: Appointed New England district manager, with headquarters in Boston, for Kidde Aero-Space Division, Walter Kidde & Co. Inc.

Ralph A. Escribano: Former sales manager for Delta Design Engineers and president of Public Relations International in San Diego, appointed general manager of Instrumentation and Control Engineering, a division of Miles-Samuelson, Inc.

William G. Dunn: Former lead engineer of the acoustic test section of North American Aviation, Inc.'s Dynamics Laboratory, Columbus, Ohio, joins Tenney Engineering, Inc. as manager of new acoustics division in Union, N.J.

Z. W. Pique: Elected vice president-marketing of Statham Instruments, Inc., Los Angeles.

Edgar M. Shurtleff: Named director of research and development of Special Devices, Inc., Pacoima, Calif. Formerly was head, advanced design section, McCormick Selph Associates; senior engineer with The Martin Company and Asst. Prof. of math & physics at Salem College.

Raymond H. Heller: General manager of Robertshaw-Fulton's aeronautical and instrument division, elected assistant vice president of the corporation.

Dr. Frank E. Sorenson: Former executive secretary of The Link Foundation, New York, N.Y., elected chairman of the Technical Assistance Board. **Miss Marilyn C. Link,** former administrative assistant at General Precision Equipment Corporation, replaces Dr. Sorenson as executive secretary. **Dr. Wayne O. Reed,** Deputy Commissioner, U.S. Office of Education, appointed to the Technical Assistance Board.

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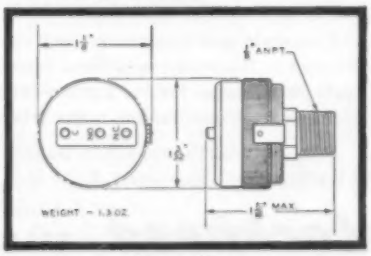

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Missile/Satellite Defense Debated

Three services have three answers to Soviet threat—Army tells Congress it should get go-ahead for Nike-Zeus, Air Force calls for satellites, Navy urges seaborne system

by James Baar

A POTENTIAL interservice bloodletting of large-scale proportions over missile and satellite defense is in the knife-honing stage.

All three military services—particularly the Air Force and Army—quietly drew up the battle lines this last week in an opening series of hearings before the House Space committee.

One by one the Pentagon's top R&D officials testified before the committee that the development of an active missile and satellite defense system is one of the most serious problems that the nation faces in the 1960's. Then each proceeded to stake a claim on how to do it.

–Richard S. Morse, Army Director of R&D, said the Army should be permitted to proceed immediately with limited production of the Western Electric *Nike-Zeus* antimissile missile.

–Lt. Gen. Bernard Schriever, commander of the Air Research Development Command, said the Air Force "believes an active (missile) defense system based on satellites offers the greatest promise."

–Rear Adm. Thomas F. Connolly, Assistant Chief of the Bureau of Naval Weapons, urged the development of a seaborne satellite defense system.

• **Why not 150 Red ICBM's**—Meantime, the threat of the growing Missile Gap was re-emphasized in the Senate.

Sen. Stuart Symington (D-Mo.), taking the floor to answer GOP statements that the Missile Gap is a fiction, said "there is a long-range Missile Gap today and there will be one for some time to come." He said the need for closing it "has been recognized" by the Kennedy Administration.

Symington said America's only "long-range missile plant in production, if called upon to do so, could produce missiles at a rate of one missile per day." Then he asked pointedly:

"In view of this fact, is it reasonable for anyone to assume that an estimate of 150 missiles produced and deployed by the Russians over the past two years is far too high?"

Current informed U.S. estimates of Soviet missile strength range from about 50 to 150 ICBM's plus several dozen or more short-range missiles deployed aboard Soviet Conventional submarines. The United States today has about six to nine operational *Atlases* and 32 *Polarises* aboard nuclear-powered submarines.

"To see where we are lacking," Symington told the Senate, "to admit it and to see about correcting it, is a mark not of weakness but of strength."

• **Zeus sparks fight**—The missile and satellite defense fight centers on the Army drive to commit *Nike-Zeus* to production.

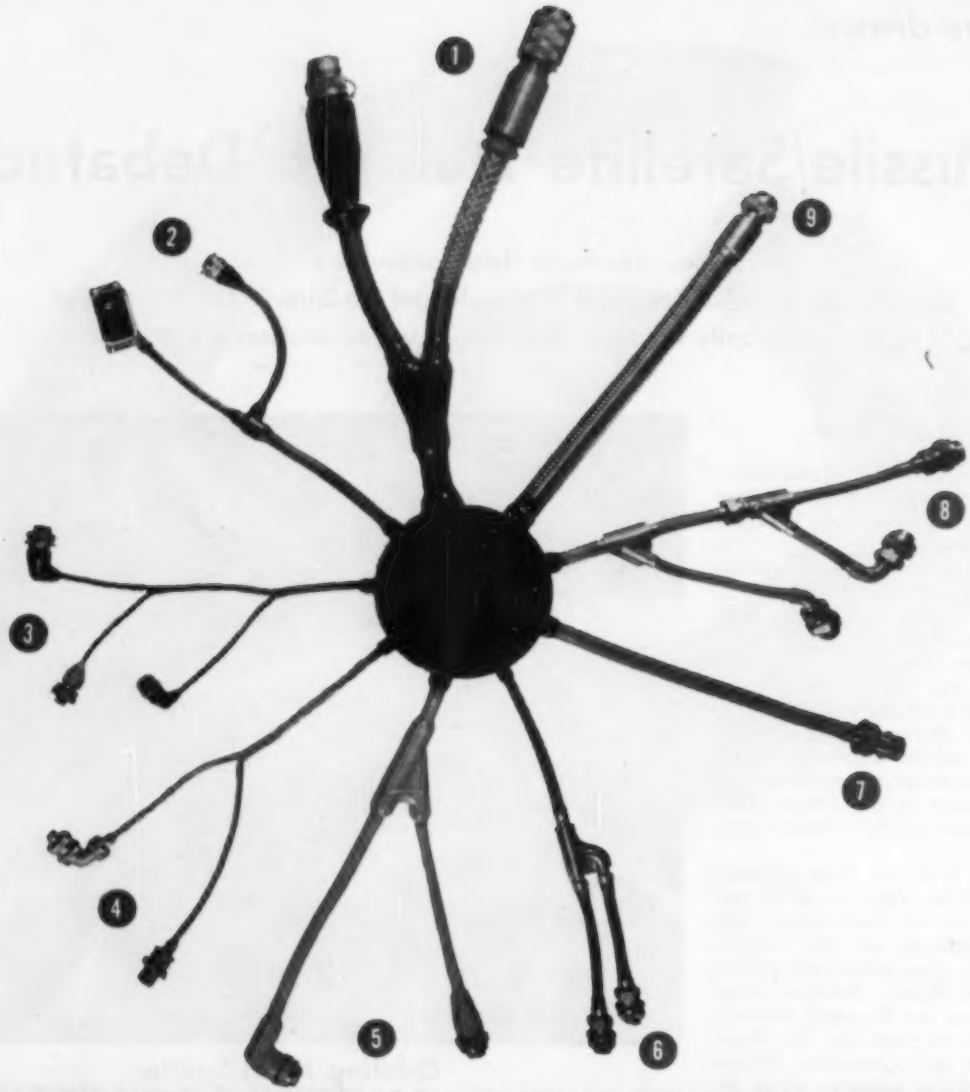
Morse told the Space Committee that in the last year very substantial progress has been made on the *Zeus* effort. He said that "many of the difficulties with which we were faced—high-powered radars, development of very high-powered tubes, questions of fast take-off of the missile—have been solved essentially."

He urged that, in the light of this and the continuing "urgent requirement for an antimissile defense," the Army should be authorized to proceed with early limited deployment of *Zeus* in order to buy time.

The cost of such a program is estimated at about $270 million for the first 18 months (M/R, Jan. 30). At the end of the first year or so, the program could be greatly expanded without any loss of time. The full pro-

Orbiting ICBM Spotter

ARTIST'S CONCEPTION of an orbiting patrol vehicle with radar, optical and infrared equipment scanning the earth to detect and track hostile ICBM's from the moment of launch. A fleet of 144 such vehicles in circular orbits has been proposed by Martin N. Kaplan, senior research engineer at Ryan Electronics.



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gram sought by NORAD would cost about $8 billion.

Morse noted dryly that the sum required for limited *Zeus* production in FY '62 "is a very small number compared with most programs (and) almost any Air Force program. . . ."

"*Zeus* is the only possible system which can be produced and deployed within the next decade," he added.

However, only a few days before Morse testified, the committee heard far less than enthusiastic huzzahs for *Zeus* from Dr. Herbert York, Pentagon Director of R&E.

• **Red missile defense**—York said that last year he was "not sold on going into production or deployment of the *Zeus* program" and this year he felt "the same."

"You want to see the thing perfected," one congressman asked him rhetorically. "There are still a lot of flaws that must be overcome and you are not ready to go into production."

"The question," York said, "is whether it will work at all."

Air Force officials testifying before the committee carefully avoided making any direct comment on the value of *Zeus*. When asked about the big antimissile missile, Dr. Joseph V. Charyk, Air Force Undersecretary, said:

"There is evidence that the Soviets are working toward a solution to the anti-ICBM problem. I think the anti-ICBM problem is one of the most important areas that we have."

Schriever said "defense against ballistic missiles is perhaps the most crucial area of development." He said, "If one nation develops one before the other it could give it a decisive edge."

Then, without commenting on *Zeus*, he said that on the basis of Air Force studies, an antimissile satellite offered the greatest promise to solving the problem.

The statement was a clear reference to recent Air Force studies of an active *Saint* satellite system. The initial *Saint* study being conducted by RCA for the Air Force called for only a satellite inspection system. An active *Saint* would be capable of both inspecting a satellite and neutralizing it if it were hostile. Such a system also might be developed to intercept ICBM's during the powered phase of flight.

An anti-missile satellite is part of overall Air Force plans for a military space program over the next 10 or 15 years. Charyk said these plans include satellites for communications, early warning and reconnaissance.

"Beyond these there are a whole series of activities," he said. He was not asked to elaborate. However, these "activities" are known to include both offensive and defense space systems that would be manned and unmanned. All are currently under study by a special committee set up by Schriever to survey military space possibilities through the middle of the 1970's.

Schriever told the committee he expected to receive the report about March 1. ⌗

Defense Notes from the Capital

• More than 43% of the $773 million in projects included in the Military Construction Bill submitted to Congress for FY '62 are for missile facilities. The biggest slice is $251.9 million for ICBM bases. This item includes facilities for six *Minuteman* squadrons—300 missiles—and one mobile *Minuteman* unit. There are also funds for the last two *Titan II* squadrons—18 missiles—at Griffis AFB, N.Y.

• The Air Force disclosed that it is trying to develop a carbon cloud decoy to blind infrared missile guidance systems. The carbon cloud would form a screen that would prevent an IR detector from "seeing" a heat source. The Air Force believes that Russia is "very active in the infrared field."

• Here is how the space pie is now cut in the Pentagon. The Air Force has 87% of the programs. It spent 91% of the money for itself or others. The final Eisenhower budget provided a total of $850 million for military astronautics for FY '62. According to R&E Director Herbert York, this includes everything that can be identified with space and space support. The FY '61 budget provided only about $500 million; the FY '60 about $400 million. But these totals did not include a number of support items.

• Rear Adm. Thomas F. Connolly, assistant chief of the Bureau of Naval Weapons, handed Congress a list of "10 main astronautics endeavors that will provide direct and significant improvements to the nation's sea power." The list: A satellite defense system, tactical booster for naval operations suitable for sea launch, space surveillance system, reconnaissance satellite, navigation satellite, geodetic satellite, meteorological satellite, several communications satellites and a global ground environment for space operations. Connolly said the "tactical booster" could be a *Sea Scout*—a *Polaris A-1* plus the upper two stages of *Scout*, ABL 248 and ABL 254. He said the *Sea Scout's* payloads could be increased from 300 pounds to about 500 by using the *Polaris A-2* and *A-3* now under development. ⌗

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Three Astronauts picked . . .

Man-in-Space Passes 'Milestone'

MANNED ORBITAL flight in 1961—a goal discounted by the U.S. for the last several months—once again seems possible as the result of last week's completely successful *Mercury Atlas* 2 flight.

Jubilant officials of the National Aeronautics and Space Administration—who breathed a collective sigh of relief as the *Atlas* passed safely through its "max Q" at T + 60 seconds—declared that major slippage in the *Mercury Atlas* program now seems ended by the *Atlas* fix.

Mercury director Robert R. Gilruth called the flight a "successful and very significant milestone" and promptly chose three astronauts for final training for the suborbital *Mercury Redstone* flight a month or two hence.

Three changes were made to beef up the front end of the *Atlas* and the interstage area between booster and capsule:

–The adapter ring was strengthened by addition of cross-members and stringers (longitudinal members).

–The fore portion of the *Atlas* was strengthened by adding an 8-in.-wide stainless steel band, of about the same (classified) thickness as the missile skin itself.

–The elbow-shaped oxygen vent valve atop the *Atlas* LOX tank was given a new kind of bracing.

The booster and capsule came perfectly through the high air loading (Q) on the upward flight that apparently caused explosion of the first *Mercury Atlas* last July 29 and the *Atlas-Able* lunar probe Dec. 14. Officially, however, the cause of both explosions has never been found.

The capsule itself came down unscathed from buffeting of up to 16½ g, more than twice the normal re-entry load. Gilruth said there is no doubt a man would have survived the flight, which duplicated the most severe re-entry path the capsule could take after emergency abort during an attempt at orbital launch.

In addition to doubling the g load, the flight provided 30% higher re-entry heating rate, temperatures 25% higher on certain capsule points and three times the normal re-entry air load—up to about 900 lbs./sq. ft. Inside the capsule, however, temperature never went over 90°F—that of a warm summer's day.

SHEPARD

GLENN

GRISSOM

Performance was so close to nominal that sources at NASA headquarters said there is little need to examine the telemetry to be certain that MA-3, the next *Mercury Atlas* flight, will proceed to the next experiment—injection of an empty capsule into orbit and immediate re-entry command. The flight will take place a short time after the Air Force delivers the first of its strengthened *Atlases*, with skin about double normal thickness at the front end—similar to those the AF has been using on *Samos* and *Midas* launches.

NASA used a thick-skinned *Atlas* on its *Big Joe* flight Sept. 9, 1959. However, thin-skinned *Atlases* were diverted from missile production lines and used for MA-1 last July and the two unsuccessful *Atlas-Able* vehicles used to attempt lunar orbit in 1960.

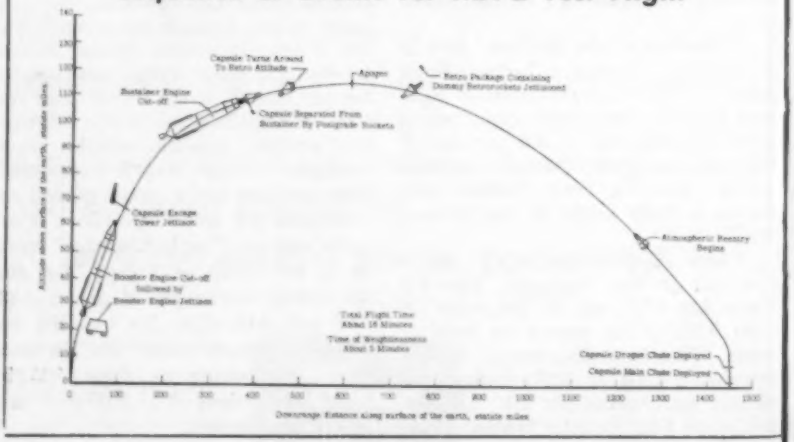
The three astronauts, chosen by Gilruth, include one test pilot each from the Marine Corps, the Navy and the Air Force.

The Marine is Lt. Col. John H. Glenn Jr., 39, oldest astronaut and a hero of two wars who has been awarded the Distinguished Flying Cross five times and the Air Medal with 18 clusters. In an F8U fighter in July 1957 he set a Los Angles-New York speed record of 3 hours 23 minutes, in the first transcontinental flight to average supersonic speed.

The Navy man is Cmdr. Alan B. Shepard Jr., 37, an Annapolis graduate who served on a destroyer in World War II, learned flying after the war and flew from a carrier during the Korean War. Shepard, a graduate of the Naval War College, tested the F3H Demon, the F8U Crusader, the F4D

(continued on page 86)

Sequence of Events for MA-2 Test Flight


Capsule Turns Around To Retro Attitude
Apogee
Retro Package Containing Dummy Retrorockets Jettisoned
Sustainer Engine Cut-off
Capsule Separated From Sustainer By Posigrade Rockets
Capsule Escape Tower Jettison
Booster Engine Cut-off followed by Booster Engine Jettison
Atmospheric Reentry Begins
Total Flight Time About 18 Minutes
Time of Weightlessness About 5 Minutes
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Capsule Main Chute Deployed
Altitude above surface of the earth, statute miles
Downrange Distance along surface of the earth, statute miles

Life shortened . . .

Transit III-B Qualified Success

Failure of payloads to separate from upper stage will limit its usefulness; operational target date of 1962 remains unchanged

THE 1962 TARGET date for an operational navigation satellite system still stands despite only "limited" success in last week's launch of *Transit III-B*. The *III-B* and its pickaback *LOFTI* satellite failed to separate from their second-stage booster and all three vehicles went together into orbit.

Scientists at Applied Physics Laboratory, Navy's system contractor for the navigation satellite program, said principal result of the separation failure would be a much shorter life—a few weeks instead of the hoped-for three years. Otherwise, the satellites will accomplish their objectives to at least a limited degree.

Instead of the intended 500-mile high circular orbit, the satellites and their booster case were injected into an ellipitical orbit with a 617-mile apogee and 104-mile perigee on Feb. 21.

Transit III-B, the third to be put into orbit, carried for the first time a new magnetic memory unit—a key component in the future operational system. This unit, as well as other payload equipment, was "working 100%," according to APL. Radio signals were "slightly impaired," however, apparently due to interference with antenna wave patterns.

This signal impairment will have considerable effect on the *SECOR* experiment planed for the mission. The *Transit* carried a transponder to be used with the *SECOR* electronic measuring system (M/R, 5/16/60) to provide Army map makers with precise geodetic position data.

Signals were also being received from the 54-pound *LOFTI* although, here again, their poorer quality may degrade their usefulness. The smaller satellite was to be used to study transmission characteristics of very low frequency (18 kc) radio waves through the ionosphere.

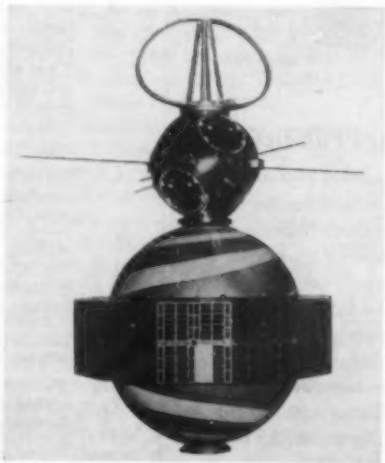
Transit III-B was boosted into orbit by an AF *Thor Able-Star*, the same rocket used for previous *Transit* and *Courier I-B* launches. Navy is currently campaigning for authorization to use a *"Sea Scout"*—two-stage *Polaris* with two *Scout* stages—as a launch vehicle for operational *Transits* which will weigh 50-100 pounds. They say present launch vehicles cost about $5 million each while the *Sea Scout* would cost less than $1 million per shot.

The present *Scout* vehicle—which saw its first space success Feb. 16 (see story, p. 84)—in fact, already uses an "old" *Polaris* for its first stage. The second stage is a modified Army *Sergeant* and the third and fourth are motors developed by Hercules Powder at Navy's Allegany Ballistic Lab.

Once in orbit, the satellite's spin was stopped by a magnetic damping system proved out on earlier models. An internal permanent magnet causes the satellite to align itself along the direction of the earth's magnetic field to properly orient the belt of solar cells with the sun.

Payload equipment includes two ultrastable oscillators each capable of transmitting continuously on four frequencies: 54, 162, 216, 324 mc for *Transit;* 224, 421, 448 mc for SECOR.

The use of four coherent frequencies from the same oscillator is an innovation in III-B. Since the signals emanate from the same source, scientists will be able to obtain a more accurate comparison of the signals in the study of ionospheric refraction of satellite signals.



PICKABACK LOFTI rode Transit into space but failed to go into separate orbit. Visible external elements on 54-lb. satellite are loop receiving and telemetering antennas, solar cells, and earth and solar aspect detectors.

Other equipment includes four transmitters, antenna (painted silver spiral band on exterior), solar cells, memory system and time signal, nickel-cad batteries, and the SECOR transponder.

The pickaback LOFTI contains a telemetry system (5 FM/AM channels), transmitter, command receiver, two VLF receivers, antennas, and solar-cell power supply.

LOFTI is instrumented to receive 18 kc signals from Navy radio station NBA in the Panama Canal Zone and measure the intensity of the signals in the ionosphere and exosphere. It will also measure VLF energy from lightning discharges. Data received by the satellite will be transmitted via telemetry to special mobile ground stations in Texas, California, and Panama.

This launch also marks the first use of a data injection station which would be used in the operational navigational system. The station, at Applied Physics Laboratory, beams the predicted orbits of the III-B to the experimental magnetic memory in the satellite. The III-B returns the data to stations on the earth, providing them continually with its current orbital data. The III-B will be the first satellite to broadcast its own precise position to earth. This information will be used by ships to make their own navigational fixes.

New orbital data will be fed to the satellite approximately every 12 hours. New data erases the old. The satellite's new intelligence is checked against the master memory in the injection station and another half-day of orbital broadcasting commences. Broadcast interval is once every 11.18 seconds. The memory and its transmitters are triggered for each read-out by a pulse from a frequency divider—a series of 25 transistorized circuits.

The counter digests the three million pulses a second coming from the ultrastable crystal oscillator, and reduces them to one precise and extremely accurate sparking signal. This pulse beamed in strength from the satellite directly to earth could be used as a near-absolute time standard accurate to the same precise degree anywhere.

The III-B has a more powerful and reliable power source than previous *Transit* satellites. ■

Discoverer Advances on Five Fronts

Only setback is failure to recover Discoverer XX capsule; bonus comes in success of Midas tracking

THE AIR FORCE *Discoverer* program had five significant new achievements and one less significant failure on its record this week. The credits:

–First restart of an *Agena B* engine in space with *Discoverer XXI*.

–Heaviest satellite yet orbited in the series, the 2,450-lb. *Discoverer XX*.

–Use for the first time in the program of a modified fuel for the *Thor* first stage, upping thrust from 150,000 lbs. to 165,000 lbs.

–Successful multiple tracking test for the *Midas* program.

–Launch of two *Discoverer* satellites within a 27-hr. period.

The failure: Unsuccessful attempt to return the *Discoverer XX* capsule, due to an equipment malfunction in the satellite.

In view of previous successful recoveries, program personnel did not consider this a major setback, although it might affect the date of the first *Discoverer* monkey shot. Some sources said this was scheduled for *Discoverer XXII* next month.

"Telemetry data is being analyzed to determine the cause of malfunction," Ballistic Missile Division reported.

Discoverer XX was launched from Vandenberg Air Force Base at 12:25 p.m. on Feb. 17. Next day, at 2:58 p.m., *Discoverer XXI* roared aloft.

The double launching gave the Air Force the first opportunity to test its multiple tracking capability for the *Midas* program.

"This seemed a good time to see what we could do," a program officer said. The tracking test was a bonus, not a result of special scheduling. However, launch of *Discoverer XXI* was delayed about three hours to provide telemetry spacing for the two satellites. Previous *Discoverer* launchings had been spaced at least six days apart.

Discoverer XX was not scheduled as a *Midas* experiment although both satellites employed the second stage Lockheed *Agena B*. The recovery effort was the longest yet planned.

BMD did not announce immediately whether the attempt to eject the capsule failed or whether it was lost after ejection. The satellite itself is expected to remain in orbit up to six months.

The experiment was part of a continuing program to develop a "space bus" testbed for a variety of other experiments, including the long overdue effort to put a small monkey into orbit.

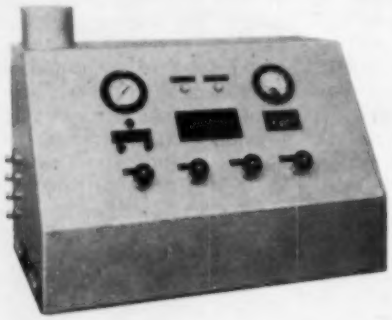
Apogee was given at 400 miles; perigee, 201.9 miles; period, 95.6 minutes.

Discoverer XX's first stage was a 56-ft., 108,000 lb. *Thor* DM-21 with a block two engine employing for the first time a modified RJ-1 fuel slightly denser than standard kerosene base propellant. Thrust developed was 165,000 lbs.

The second stage was standard in dimensions, 25 ft. in length and 5 ft. in diameter, but weighed 15,800 lbs. at launch compared to 15,500 lbs. for the *Discoverer XXI* second stage. Thrust was the same at 15,000 lbs.

First test of the *Agena B* restart capability in orbit was made with *Dis-*

(Continued on Page 86)



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NASA May Ask for Extra $200 Million

THE NATIONAL Aeronautics and Space Administration is considering a request to President Kennedy for 1962 budget increases to speed and increase the scope of *Saturn*, *Centaur*, nuclear propulsion, the F-1 engine, lunar and planetary exploration and meteorological satellites.

NASA headquarters has tentatively decided to reject a proposal by its launch vehicle office to spend $10 million in the coming year on a start on a giant segmented solid booster rocket.

The wind may blow either way on the biggest project involved in the space agency's budget discussions—the Project *Apollo* three-man space capsule.

The odds are that funds will be sought above the Eisenhower budget for *Saturn*, *Centaur*, nuclear propulsion, the F-1 engine, lunar and planetary exploration and meteorological satellites. The exact amount has not leaked out of the highly confidential discussions, but a good guess on the total might be $150-$200 million over the Eisenhower budget, exclusive of whatever is done about *Apollo*.

The *Saturn* funds will go almost completely for speeding the C-2 vehicle. *Saturn* C-1, the first, three-stage version of *Saturn*, seems to be just about fully funded. Extra money could speed the development of the J-2, 200,000-lb.-thrust liquid hydrogen engine at Rocketdyne, and might make it possible to award a development contract sooner on the giant S-II stage, a cluster of four J-2 engines. The Eisenhower budget provides only $3.1 million for the C-2, which provides for only a month or two of contractor work, late in the fiscal year, on the S-II stage.

Additional money for *Centaur* could authorize overtime work at Convair and Pratt & Whitney to speed the final phase of development, and authorize procurement of more vehicles when the development is complete. It also could speed up some of the supporting research in other places.

Nuclear propulsion development could be accelerated by providing money for engine hardware work during FY '62. And, if there were desire to go full speed in developing nuclear propulsion, parallel work could be started on the vehicle with an airframe contractor.

The F-1 engine—which may provide the basic propulsion unit for the manned lunar mission—could be speeded by authorization of overtime at Rocketdyne.

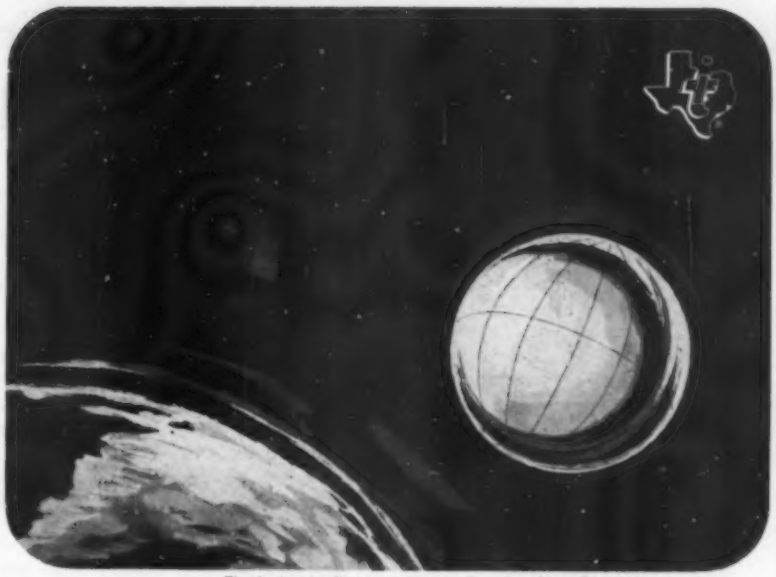
NASA headquarters officials feel the number of lunar and planetary launches on the program is strictly nominal. Additional money could provide more backup vehicles and payloads and more frequent shots. They caution, however, that the effect of speeding the program can't be felt for at least a year. It takes that long to schedule booster production.

The question under meteorological satellites is how fast to move into an operational system. The Weather Bureau and other operational weather data users are enthusiastic about the results of the first two *Tiros* shots. They want to have satellites up on a year-round basis. So far, under the Eisenhower budget guidelines, NASA has been unable to do that much. Under the new administration, it will be able to do more.

The NASA headquarters reasoning on the big solid rocket is that one more interim step should be performed before developing a booster as big as the F-1. The $3.1 million in the Eisenhower budget will provide funds for the interim step—a single segment weighing perhaps 60,000 or 70,000 lbs.

The question on *Apollo* does not revolve around technical questions. NASA is hesitant to propose speedy development of the big manned spacecraft—although it is already on the public record in favor of doing so—because it does not yet know the attitude of the Kennedy administration toward manned space flight.

Many members of President Eisenhower's Science Advisory Committee were opposed to carrying man-in-space beyond *Mercury* because of the great drain they said it imposed on the nation's scientific resources. The same scientists, although with a different chairman, are advising President Kennedy. There is still no word on Kennedy's attitude.



TI electronic flight control in Douglas Aircraft's Delta launch vehicle helped orbit the NASA communications satellite ECHO I.

TI FLIGHT CONTROLS IN SPACE EXPLORATION

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Silo Accident Cost May Hit $300,000

DAMAGES UP TO $300,000 may have been caused when a huge crane exploded and fell into an *Atlas* silo at Roswell, N.M.

The Feb. 16 tragedy took the lives of six workers and injured 13 others.

The property damage figure is a preliminary rough estimate by the Army Corps of Engineers. The final figure will not be known until two boards of inquiry complete their reports, perhaps this week.

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Inquiries should be addressed to:
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NASA Flight Research Center
P. O. Box 273
Edwards, California

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NASA

Explorer IX—First Satellite Orbited by All-solid Vehicle

VISUAL AND photographic sightings of *Explorer IX*, a 12-ft. balloon satellite, are enabling scientists around the world to figure the density of the thin atmosphere between 400 and 1600 miles altitude.

Failure of a radio beacon will make it harder to track the aluminum-coated plastic sphere. But its reflectivity of 80% makes it as bright as a fourth-magnitude star while it is out of the earth's shadow.

Even more important than the satellite experiment were two important firsts chalked up by the *Scout* launching vehicle on Feb. 16:

–It was the first satellite ever put into orbit with an all-solid-propellant vehicle—a powerful argument in support of the current proposals for a big solid-propelled space booster.

–It was the first satellite launched from the civilian-operated Wallops Island, Va., station of the National Aeronautics and Space Administration —evidence that scientific satellites can be launched from a small installation with relatively inexpensive facilities and a small permanent staff.

• **'Poor man's model'**—*Scout* has been dubbed the "Poor Man's Rocket" because it is the first with orbital capability whose launching cost is expected to be under $1 million. That figure does not, of course, include development costs.

The orbital attempt succeeded on the fourth launching of a full four-stage vehicle and the second attempt at orbit. The *Scout* is now halfway through its development program, which is to be completed with four more launches in the next 12 months.

Payloads to be carried by the next four *Scouts* are *S-55*, a micrometeorite measuring satellite; and *P-21* and *P-21a*, two space probes for measuring electron density. The fourth will be a vehicle for back-up in case one of the others fails.

The *Explorer IX* payload weighed 87 lbs., of which 14 lbs. was the inflatable satellite and 73 lbs. was the satellite ejection and inflation equipment, the fourth stage telemeter system and such necessary hardware as the metal container in the nose of the fourth stage. The rocket case and payload container, which followed the sphere into orbit, weighed about 130 lbs.

The aluminum-plastic material of the sphere is 0.002 in. thick, about four times as thick as the skin of the *Echo* 100-ft. balloon satellite, and thus considerably more rigid. NASA said the 12-ft. *Explorer IX* sphere is expected to retain its rigidity even when pierced by micrometeorites. *Echo*, by contrast, has become quite wrinkled in the six months since it was launched.

The material consists of two layers of Mylar and two of aluminum foil, each about 0.0005 in. thick, bonded into a four-ply arrangement with the aluminum on the exterior. A 2¼-lb., 3 in. by 4 in. radio beacon, powered by 280 solar cells and miniature storage batteries, was to have aided in tracking. However, the radio failed on the first circuit of the earth, somewhere between Woomera, Australia, and San Diego, Calif.

Fortunately, however, NASA scientists had decided to add a small battery-powered tracking beacon to the fourth-stage rocket. This radio operated and provided the first confirmation that the rocket case was in orbit. It was not until late on the afternoon of Feb. 17 that it could be confirmed through optical and photographic sightings that the balloon itself was in orbit.

The orbital life of the balloon may be anything from a few weeks to a year. It depends on the exact density of the atmosphere at its altitude—something science does not yet know. The orbit has the programed perigee, but apogee is over 300 miles higher than the 1275 miles programed. ⁂

SCOUT LIFTS Explorer IX into orbit in successful Feb. 16 firing at Wallops Island.

Aerospace Aims to Triple Technicians

LOS ANGELES—Upcoming decisions to be made by the Kennedy Administration will determine the extent to which Aerospace Corp.'s role will affect industry-Air Force relationships.

Dr. Ivan Getting, president of Aerospace, said the firm establishment of roles and missions in carrying out space activities will be necessary before an estimate of his company's eventual future size can be made.

In its basic function as a third party in industry-Air Force intercourse, Aerospace will exercise less detailed control of programs than that practiced by Space Technology Laboratory during its tenure in a similar role. Dr. Getting subdivided his organization's operations into three segments: Advanced planning, systems research, and general systems engineering and research.

"Aerospace is to be the technical arm of the Air Force in the fields of ballistic missiles and space systems," he said, declining to specify all the programs now "in-house."

"A three-fold increase in technical personnel is desirable, before we can hope to be in reasonable control of the job we have been asked to do," he continued. The company now employs about 2000 persons, of whom 400 are technical personnel and the remainder administrative and support.

• **Workload**—About 20 programs and projects are now under Aerospace's cognizance, 12 having been inherited from STL last summer when Aerospace was formed. With the acquisitions, Aerospace also got about 250 STL people. The firm is also conducting studies in applied research management.

Included in the 20 programs are *Dyna-Soar, Advent, Midgetman* ICBM, *Saint, Midas, Samos, Mercury, Transit, Bambi* and *Vela Hotel*, among others of a classified nature. The *Transit* satellite launch scheduled for later this month will be the first Aerospace-managed space shot, Dr. Getting said.

The third-party role of Aerospace is expected to make some very complex contractual arrangements, due to the fact that the responsibility of a contractor cannot be spelled out as specifically as sometimes desired, Dr. Getting said.

"Aerospace will provide technical supervision and other assistance to the Air Force, without diminishing the responsibilities of the contractors to perform as required," he said, adding that some companies are in extremely competitive positions and therefore are not always candid.

He likened his company to an architect-engineer in the weapon system development field.

Contractural clauses arrived at by Aerospace for inclusion into future agreements will carry forward an established practice set forth by STL in its relations with industry.

In its technical direction of Air Force programs, Aerospace will spell out contractor responsibility, define interface areas and make various subsystems compatible. This technical direction he defined as the job of modifying contractor activity to the benefit of the Air Force.

The degree of direction will not be as high as that practiced previously, Dr. Getting pointed out, estimating that Aerospace expects to assign about 40 to 50 technical personnel to each major program, whereas STL had about 250 people per program. Aerospace will get into extremely fine detail only where absolutely required, he added, comparing Aerospace's role for the future with that role filled by STL through 1957.

• **Teers**—Aerospace's laboratories will check out conclusions drawn by other organizations in connection with Air Force programs.

"It is not that these other organizations are considered incapable of drawing proper conclusions," he emphasized, "but if we are to function properly here, we must treat others as peers, and in turn be treated as a peer.

"So, even though scientists as a whole are quite rational and objective, they are, after all, human beings and therefore susceptible to becoming salesmen for their own concepts and systems. We merely want to insure that the semantics and other terms of reference are defined in the same manner by all parties," he stated.

In addition to its monitoring functions, Aerospace will also conduct its own original research work. As an example, Dr. Getting noted that physicists at the company had recently achieved a ten-microsecond plasma of about 300,000 degrees.

Another possible field of interest is one suggested by Trustee Trevor Gardner at a recent board meeting of the company. Gardner advocated that Aerospace support research into the use of outer space as a medium for arms control on earth. Dr. Getting indicated this might be done, and said he sees no contradiction between this and the firm's role as an arms maker.

TI electronic flight control in Douglas Aircraft's Delta launch vehicle helped orbit the NASA weather satellite TIROS II.

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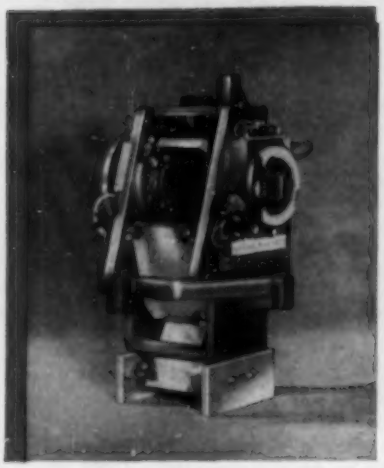
PRECISE STAR TRACKER



A celestial navigation system called for a tracking device capable of establishing a line of position within an accuracy of 300 feet. Kollmorgen came up with a constant deviation elevation system that positions a movable mirror, in relation to the fixed elements, to a repeatable accuracy of better than 5 parts in a million.

This compact package represents a combination of highly precise optical and electronic units in a housing only 6 x 6 x 10 inches. Kollmorgen's project from concept to installation, it is a typical demonstration of the company's scientific, engineering and manufacturing skills in optics, electronics, mechanics. Example: the precision optics (a prism and two mirrors) are of Kollmorgen manufacture. So, too, are the Inland torque motor*, the gearing and other precision-machined parts.

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*Product of Inland Motor Corporation of Virginia, a Kollmorgen subsidiary.

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Two Discoverers

(Continued from Page 82)

coverer XXI. This was with the last of the *Midas* experiments in the program.

The liquid fuel engine, developed by Bell Aerospace, was restarted for one second during its first pass over the Pacific Missile Range. This occurred about two hours after the 2:58 P.M. launching from Vandenberg AFB.

Designed for a useful life of only two days, *Discoverer XXI* did not carry a recovery capsule. Computed orbital life is about 150 days, according to the Air Force.

The engine restart is believed to have required less than 100 lbs. fuel during the brief burning time. The vehicle was rotated 180° following restart to reverse its position.

Success of the restart operation demonstrated the ability to perform evasive action with a *Midas* satellite as well as making orbital corrections.

Except for the restart experiment, *Discoverer XXI* was a carbon copy of *Discoverer XIX*, launched Dec. 19, 1960. Test objective for both vehicles was the collection of engineering and research data on the atmospheric phenomena and infrared radiation in the earth's atmosphere. Data obtained will be needed to support the advanced *Midas* R&D program.

The first stage developed 150,000 lbs. thrust with standard RJ-1 fuel.

Period of the test vehicle was lengthened four minutes to 97.8 min. following restart with an apogee of 670 miles and 155-mile perigee.

The Air Force listed six major test objectives for the *Discoverer XX* experiment:

(1) *Agena B* systems evaluation, including launch techniques, propulsion, communications, orbital performance, recovery techniques, advanced engineering tests, special attention to proving reliability of re-entry, recovery techniques.

(2) Evaluation of stabilization-system modifications made to overcome instability problems of some previous *Discoverer* flights.

(3) Improvement of all systems reliability to achieve 4 days in orbit before recovery.

(4) Evaluation of components in the radio command guidance system.

(5) Radiation background measurements.

(6) Determination of high energy protons effects on silicon test materials (to check space radiation on transistors and solar cells).

The 300-lb. re-entry capsule contained—in addition to the usual communications and command equipment—a precision Navy Transit tracking beacon in a joint Navy-AF experiment to further evaluate the Transit satellite tracking technique. Two Navy transmitters provided signals for Doppler shift experiment. ⁂

Mercury Success

(Continued from Page 80)

Skyray and the F11F Tigercat before becoming project test pilot on the F5D Skylancer and an instructor at the Navy's Test Pilot School, Patuxent, Md.

The Air Force man is Capt. Virgil I. Grissom, 34, who flew 100 combat missions with F-86s in Korea, for which he was awarded the Distinguished Flying Cross and Air Medal with Cluster. He was a jet pilot instructor from 1952 to 1955, studied aeronautical engineering for a year and then became a test pilot in 1957.

Gilruth said he chose the three astronauts on the basis of evaluation of medical and technical information accumulated during the initial pilot selection process and the 22-month training program.

He pointed out that all seven astronauts will be eligible for selection for later ballistic and orbital flights, on the basis of similar evaluations. All seven will work together during actual flight operations—the six remaining men on technical support and communication assignments.

The final selection of the astronaut for the manned *Redstone* flight will be made just before the flights, Gilruth said. It was understood the three will be narrowed to two about 48 hours before the flight and that the third astronaut will be assigned to voice communications at Grand Bahama Island. Both of the remaining men will prepare for the flight, so that the second man is available as back-up in case the first suddenly becomes ill. The backup man will be voice communicator at the Cape.

The timetable for the 1424-mile MA-2 flight Feb. 21 was almost as rapid as that for the 235-mile MR-1 last Dec. 19. Liftoff at 9:10 a.m. was followed by acquisition of the signal by a downrange search plane at 9:21, impact at 9:28, visual sighting at 9:32, pickup by helicopter at 9:53 and delivery to the deck of the U.S.S. Donner at 10:06—56 minutes after liftoff.

The MA-2 capsule reached an altitude of 107 statute miles and maximum velocity of 12,850 mph before landing 1424 miles downrange, 410 miles east northeast of Roosevelt Roads, Puerto Rico. This compared with nominal altitude of 115 miles and range of 1400 miles. ⁂

—when and where—

MARCH

Optical Society of America, Roosevelt Hotel, Pittsburgh, Mar. 2-4.

Gas Turbine Conference and Exhibit, sponsored by Gas Turbine Power Division of American Society of Mechanical Engineers and U.S. Department of Defense, Shoreham Hotel, Washington, D.C., Mar. 5-9.

Eleventh Annual Instrument Society of America, Conference, Roosevelt Hotel, Pittsburgh, Mar. 8-10.

Second Symposium on Engineering Aspects of Magneto-Hydrodynamics, University of Pennsylvania, PGNS, AIEE, IAS, University Museum, Philadelphia, Mar. 9-10.

Institute of the Aeronautical Sciences, Flight Propulsion Meeting (classified), Cleveland, Mar. 9-10.

American Society of Mechanical Engineers, Aviation Conference, Statler Hilton Hotel, Los Angeles, Mar. 12-16.

American Rocket Society, Test Operations and Support Conference, Biltmore Hotel, Los Angeles, Mar. 13-16.

1961 Missile/Space Conference and Goddard Memorial Dinner of the National Rocket Club, Sheraton Park Hotel, Washington, D.C., Mar. 14-16.

Inter-Station Supersonic Track Conference (confidential), Supersonic Track Symposium, U.S. Naval Ordnance Test Station, China Lake, Calif., Mar. 14-16.

Fifth National Conference on Aviation/Space Education, Mayflower Hotel, Washington, D.C., Mar. 16-18.

American Astronautical Society Symposium, Interactions of Space Vehicles with an Ionized Atmosphere, co-sponsored with AFOSR and ARPA, Sheraton Park Hotel, Washington, D.C., Mar. 17.

American Congress on Surveying and Mapping, and American Society of Photogrammetry, Convention, Shoreham Hotel, Washington, D.C., Mar. 19-25.

IRE International Convention, Coliseum and Waldorf-Astoria Hotel, New York City, Mar. 20-23.

American Society for Metals, 12th Western Metal Exposition, Pan-Pacific Auditorium, Los Angeles, Mar. 20-24.

23rd Annual American Power Conference, Sherman Hotel, Chicago, Mar. 21-23.

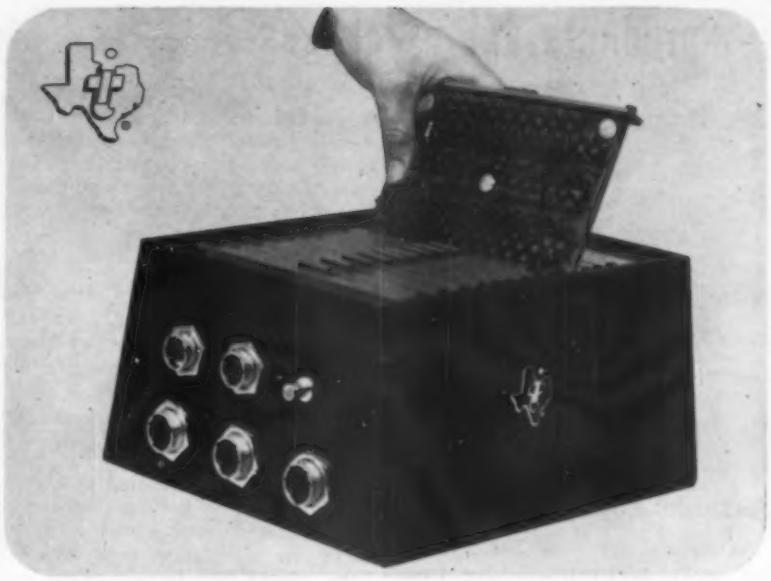
American Meteorological Society, General Meeting, Chicago, Mar. 21-23.

American Chemical Society, 139th National Meeting, St. Louis, Mar. 21-30.

4th Symposium on Temperature, Its Measurement and Control in Science and Industry, sponsored by ISA, AIP, NBS, Veteran's Memorial Hall and Deshler Hilton Hotel, Columbus, Ohio, Mar. 27-31.

American Nuclear Society, Nucleonics in Flight Symposium, Statler Hilton Hotel, Dallas, Mar. 28-29.

Society of Aerospace Material and Process Engineers, Filament Winding Symposium, Huntington-Sheraton Hotel, Pasadena, Calif., Mar. 28-30.



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—reviews—

MACHINING CHARACTERISTICS OF HIGH STRENGTH THERMAL RESISTANT MATERIALS, Wright Aeronautical Division, Curtiss-Wright Corp., Wood-Ridge, N. J. 181 pp., $4.60.

A study of the machining characteristics in turning, milling, drilling and tapping has been conducted on 25 high-strength thermal-resistant alloys. Relationships are presented between tool life, cutting speed, feed, tool geometry, tool material and cutting fluids.

Increased requirements are described for precise control of rigidity speeds, feeds, tool geometry for machine tools to handle these alloys. Alloys studied were of the following classes: Martensitic low-alloy steels, hot work die steels, austenitic stainless, martensitic stainless, ph stainless, nickel-base and cobalt-base high-temperature alloys and titanium.

SPACEFLIGHT TECHNOLOGY, Proceedings of the first Commonwealth Spaceflight Symposium, edited by Kenneth W. Gatland, Academic Press, New York, 365 pp., $11.

Nearly two dozen of the top European spaceflight experts contributed to this Commonwealth conference, held in 1959. In several instances, the information given in the book is of purely local interest—such things as Commonwealth university participation, Canadian facilities and Britain's place in interplanetary exploration.

Generally, however, the papers presented will be of use to many engineers and scientists in the spaceflight field. Among the topics covered are launching vehicles and space vehicles' space vehicle cabins, propulsion system, instrumentation, tracking and communication, and the exploration of the moon. This last paper deals with the minimum propulsion needed for the soft moon-landing of instruments.

PROCEEDINGS OF MEETING ON PROBLEMS AND TECHNIQUES ASSOCIATED WITH THE DECONTAMINATION AND STERILIZATION OF SPACECRAFT—JUNE 29, 1960. Jack Posner, Editor. Appendix: Sterilization of Interplanetary Vehicles. Charles R. Phillips and Robert K. Hoffman. Order NASA Technical Note D-771 from National Aeronautics and Space Administration, Washington 25, D.C. 57 pp., $1.50.

A meeting was held by representatives of agencies concerned with the development of space vehicles and those investigating decontamination and sterilization procedures. The conferees recommended that: (1) a body of related information be accumulated, (2) standard operating procedures be established, (3) acceptable limits of contamination be determined, (4) NASA policy be clarified, (5) new sterilizing agents be developed, (6) compatibility studies be pursued, (7) sterile manufacture of parts be investigated, and (8) a working level group be formed to implement recommendations and procedures.

products and processes

Versatile Rotary Switch

A 20-amp, 600 VAC modular design rotary switch is available from American Solenoid Co., Inc. Unit can be employed for motor control up to 16 HP at 600 volts, as well as for instrumentation and control circuits.

Designated as Type C-16, this switch contains two isolated double-break silver-alloy contacts in each stage. Twelve stages can be combined to form a single column of 24 contacts. Up to 4 columns arranged in tandem can be used in a switch assembly to control up to 96 double-break contacts over 18 positions, from a single control point.

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Micron Particle Filter

Gelman Instrument Co. is producing a membrane filter, specifically designed to speed counting and sizing of contaminant particles in air, military fluids, and other liquids.

The membrane filter is a thin microporous plastic material with controlled micron size pores. The membrane filter is available in a dark green color. The color has been chosen so that almost all dirt particles are visible under the microscope. Both dark and light colored particles are clearly contrasted against the green color of the filter.

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Spectrometer Typewriter

A typewriter read-out system for direct reading spectrometers is available from Jarrell-Ash Co.

In the Typewriter Print-Out System, the spectrometric data is recorded automatically after the exposure is terminated. Carbon copies are readily made. Pre-printed or pre-typed forms may be used and complete analytical reports thus prepared. The typewriter prints a number proportional to percent concentration of the chemical elements present in the sample.

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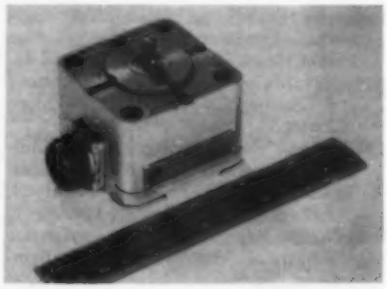

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The device is a positive displacement gear pump whose discharge is controlled by an adjustable ratchet mechanism, a single revolution clutch and a constantly running motor.

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Plug-in Transformers

A series of micro-miniature transformers with 0.030 in. diameter brass pin leads spaced .100 in. apart, to "plug in" to a standard 5 pin subminiature socket or to facilitate "soldering-in" for permanent installations, is available from James Electronics Inc. The ½ in. diameter metal cases are sealed and potted to meet MIL-T-27A, grade 5. "U" Series impedance ranges are available from 10 ohms to 300 K ohms.

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Flexible Pigtails

A series of stainless steel teflon flexible pigtails is available from The Bastian-Blessing Co. Made up of a resilient Teflon liner reinforced by a rugged stainless steel braid cover, RegO flexible pigtails are rated at 3000 psi working pressure.

These flexible pigtails have connections machined to CGA and other industry standard specifications for use with acetylene, helium, LP-gases, nitrogen, oxygen and a host of other gases or may be furnished with ¼ in. NPT female ends. All are carefully cleaned for oxygen service and individually pressure tested before shipping.

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Dust Toroidal Inductors

United Transformer Corp. is marketing eight "MQ" type permalloy dust toroids. These types provide the highest factor in their class with miniatured dimensions. All units are hermetically sealed, meet or exceed MIL-T-27A specifications and are laboratory adjusted to 1% tolerance. Hum pickup is extremely low due to the toroidal winding structure, with windings uniformly spread over the core.

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TI developed FM/FM transmitters and power supplies operated in "Ham" MERCURY spacecraft test. TI will supply FM/FM systems for later MERCURY shots.

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APPARATUS DIVISION

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Velocity Vibration Probe

Dynamic Devices is marketing a velocity type vibration probe with a moving weight of 0.1 grams. The probe has an output of 6mv/in/sec with a 40 ohm coil free to travel in excess of 3/16 in. double amplitude. This quick and easy-to-use probe has no cumbersome attachments, and is ready for immediate use by feeding the output directly to a high gain scope.

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Miniature Check Valve

A miniature check valve with a total pressure drop of less than 1 psi at rated flows, is available from Spartan Manufacturing Corp. Identified as the Spartan 606, it has a maximum cracking pressure of 8" of H_2O while total pressure drop does not exceed 20" of H_2O at rated flow. The valve is compatible with 90% hydrogen peroxide, nitric acids and other fuels.

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DC Operational Amplifier

Micro Gee Products, Inc., is producing a low cost DC Operational Amplifier designed for rack mounting in a standard 19 in. wide rack. The Model 505A consumes 3½ in. of vertical rack space, is completely self-contained, operates directly from a 115 volt 60 cps line, and features response to 5 kc and an open loop gain of 5000. A chopper stabilized version, the Model 505AS, is also available.

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Official National Aeronautics and Space Administration Photograph

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contracts

NASA

Western Scientific Instrument Company, Inc., Redwood City and Van Nuys, Calif., for calibrating, maintaining and repairing electronic instruments vital to research in space vehicles, aircraft and the physiological response of human pilots. To be conducted at Ames Research Center, Moffett Field. Amount not disclosed.

$400,000—G. T. Schjeldahl Company, Northfield, Minn., for design, development, fabrication and testing of rigidized inflatable spheres for its passive communication satellite program, Project *Echo*. Contract to be managed by Langley Research Center, Langley Field, Va. under direction of Goddard Space Flight Center, Greenbelt, Md.

$56,362—University of Alabama—(four contracts) for research to develop methods for solving guidance and control problems peculiar to multi-stage space vehicles varying from high to low thrust; a study of transient fluid heat transfer problems; a method for correlating temperature-fatigue data for metals and alloys; and theoretical study of the use of cesium in electrically-propelled space vehicles.

$53,262—University of Alabama, for analytical research on the theoretical physics of ion beam neutralization for electrically-propelled space vehicles.

$46,900—A.G.A. Corporation, Alexandria, Va., for C-Band radar beacons.

MISCELLANEOUS

$300,000—Electronic Engineering Company of California, Santa Ana, Calif., for manufacture of electronic data processing equipment, from **Sandia Corporation**, Albuquerque, N.M.

$161,637—J. A. Tiberti Construction Co., Las Vegas, Nev., from Atomic Energy Commission for construction of support facilities in the Rover Test Area of the Nevada Test Site.

NAVY

$300,000—Electronic Assistance Corp., Red Bank, N.J., for command radio receivers and transmitters to control target drones, pilotless aircraft and missiles.

ARMY

Maurice H. Connell & Associates, Inc. and **Reynolds, Smith & Hills**, Miami, Fla., for architect-engineer services for design of *Saturn* Launch Complex 37 (NASA) Facilities, Cape Canaveral Missile Test Annex, Patrick AFB, Fla. Amount not disclosed.

$3,920,391—Raytheon Co., Waltham, Mass., (two contracts) for concurrent and replenishment repair parts for *Hawk* missile system.

$967,000—Sperry-Rand Corp., Salt Lake City, for research and development on the *Sergeant* missile system.

$583,740—Western Electric Co., Inc., New York City, for production engineering services for the preparation of Misc. Ord. Documentation for the *Nike-Hercules* guided missile system.

$494,041—Cornell Aeronautical Laboratory, Inc., Buffalo, N.Y., for high-power microwave radar research program.

$101,380—General Electric Company, Burlington, Vt., for production engineering study of XM3 Timer for the XM84 adaption kit.

$64,793—Douglas Aircraft Co., Santa Monica, Calif., for field change kits and repair parts for *Nike/Ajax Hercules*.

$61,532—Sperry Rand Corp., Salt Lake City, for repair parts for *Sergeant* guided missile system.

$46,856—Electromechanical Research Co., Inc., Brooklyn, N.Y., for development and fabrication of low-drag, high-energy armor-penetrating projectiles.

$45,901—Dynametrics Corp., Burlington, Mass., for continuation of contract for design and fabrication of data recording system and associated equipment.

$32,284—University of Alabama, for theoretical study of the opaqueness of the atmosphere and its radiation temperature.

$31,402—Gilfillan Bros., Inc., Los Angeles, for replenishment requirements for *Corporal* missile system.

AIR FORCE

Hughes Aircraft Company, for *Titan* launch site activation work. Details not yet released.

$2,500,000—Rocketdyne Division of North American Aviation, Inc., Canoga Park, Calif., for technical data in support of *WS 107A-1* propulsion subsystem and related GSE.

$2,162,067—B. F. Goodrich Aviation Products, Akron, Ohio, for aircraft fuel cells and tires for the B-52 and miscellaneous Navy aircraft and electrothermal, anti-icing systems for the *Hound Dog* missile.

$151,988—Boeing Airplane Co., Aero-Space Division, Seattle, for reproducible copy and negatives applicable to *IM99A* and *IM99B* missiles, and TCTO, engineering and retrofit kits for *IM99A* missile. (3 contracts).

$200,797—A. W. Hayden Co., Div. of Consolidated Electronics Industries Corp., for stop timers, electrical type, electromagnet-operated.

$86,000—Advanced Technology Laboratories, Mountain View, Calif., for prototype systems to measure temperatures at the surface of *Dyna-Soar's* skin panels and leading edges. Subcontract from **Boeing Airplane Company.**

$31,860—McCulloch Corp., Los Angeles, controls to support target drones.

ADVERTISERS' INDEX

Aerojet-General Corp., Sub.-General Tire & Rubber Co. 12
Agency—D'Arcy Adv. Co.

Aerospace Corp. 6
Agency—Gaynor & Ducas, Inc.

Air Products, Inc. 74
Agency—Diener & Dorskind, Inc.

AiResearch Mfg. Co., Div.—The Garrett Corp. 67
Agency—J. Walter Thompson Co.

R. C. Allen, Aircraft Instrument Div. 56
Agency—Jepson-Murray Adv., Inc.

American Cystoscope Makers, Inc. .. 68
Agency—Sproul & Assoc., Inc.

American Time Products, Inc. 93
Agency—H. M. Alexander & Assoc., Adv. Agency

Avco Corp. 55
Agency—Benton & Bowles, Inc.

Bell Aerosystems Co., a Div. of Bell Aerospace Corp. 2
Agency—The Rumrill Co., Inc.

Bendix Corp., The, Scintilla Div. 78
Agency—MacManus, John & Adams, Inc.

Bristol Co., The, Aircraft Equipment Div. 75
Agency—Chirurg & Cairns, Inc.

Callery Chemical Co. 58
Agency—Ketchum, MacLeod & Grove, Inc.

Convair/Fort Worth, a Div. of General Dynamics 52
Agency—Glenn Adv., Inc.

Curtiss-Wright Corp. 69
Agency—Buchen Adv., Inc.

Delco Radio, Div.—General Motors Corp. 10
Agency—Campbell-Ewald Co.

G. C. Dewey Corp., The 90
Agency—George T. Petsche Adv.

Douglas Aircraft Co., Inc. 14
Agency—J. Walter Thompson Co.

Edgerton, Germeshausen & Grier, Inc. 38
Agency—Reach, McClinton & Humphrey, Inc.

Englehard Industries, Inc. 82
Agency—Stuart Sande, Adv.

Carl Fisher & Co., Inc. 52

General Electric Co., Light Military Electronics Dept. 43

General Electric Co., Silicone Products Dept. 3
Agency—Ross Roy-B.S.F.&D., Inc.

Grumman Aircraft Engineering Corp. 60
Agency—Fuller & Smith & Ross, Inc.

A. W. Haydon Co., The 71
Agency—Hicks & Greist, Inc.

Huyck Systems Co. 48, 49

Interelectronics Corp. 65
Agency—Meyer & Behar Adv., Inc.

Kollmorgen Corp. 86
Agency—Wilson, Haight & Welch, Inc.

Lincoln Laboratory—Massachusetts Institute of Technology 66
Agency—Randolph Assoc., Adv.

Litton Industries, Litton Systems, Inc. 63
Agency—Compton Adv., Inc.

Lockheed Aircraft Corp., Missiles & Space Div. 76
Agency—Hal Stebbins, Inc.

Magnetic Controls Co. 8
Agency—Scrymiger & Osterholt, Adv., Inc.

Metal Bellows Corp. 72
Agency—George T. Metcalf Co.

Microdot, Inc. 47
Agency—Carson/Roberts/Inc.

Missile Component Cleaning Labs .. 88
Agency—Philip Klein Adv., Inc.

National Aeronautics & Space Administration 11, 84
Agency—S. G. Stackig, Inc., Adv.

New Departure Div.—General Motors Corp. 9
Agency—D. P. Brother & Co.

Pan American World Airways, Inc., Guided Missiles Range Div. 59
Agency—Willard E. Botts Adv., Inc.

Philco, Techrep Div. 70
Agency—B. K. Davis & Bro., Adv. Service

Philco, Government & Industrial Div. . 50
Agency—Maxwell Assoc., Inc.

Powertron Ultrasonics Corp. 61
Agency—Donaldson Assoc., Inc.

Radio Corp. of America, Service Co. 54
Agency—Al Paul Lefton Co., Inc.

Reinforced Plastics, Dept. of Raybestos Manhattan, Inc. 91
Agency—Gray & Rogers, Adv.

Remington Rand UNIVAC, Div.—Sperry Rand Corp. 62
Agency—Mullen & Assoc., Inc.

Space & Information Systems Div. of North American Aviation, Inc. ... 7
Agency—Batten, Barton, Durstine & Osborn, Inc.

Space Technology Labs., Inc., sub. of Thompson Ramo Wooldridge Corp. 73
Agency—Gaynor & Ducas, Inc.

Sperry Farragut Co., Div.—Sperry Rand Corp. 64
Agency—Chirurg & Cairns, Inc.

Sperry Phoenix Co. 4
Agency—Reach, McClinton & Co., Inc.

Stillman Rubber Co. 53
Agency—McNaughton-Laub, Inc.

Technic, Inc. 79
Agency—Lanning Assoc., Adv.

Texas Instruments, Inc. 83, 85, 87, 89
Agency—Don L. Baxter, Inc.

Vitro Electronics, a Div. of Vitro Corp. of America 57
Agency—Sam J. Gallay Adv.

Washington Technological Assoc. 94
Agency—Dawson, MacLeod & Stivers

Willson Products Div., Ray-O-Vac Co. 35, 36
Agency—Howard H. Monk & Assoc., Inc.

EMPLOYMENT

Air Products, Inc. 82
Agency—Diener & Dorskind, Inc.

General Atomic Div. of General Dynamics 88
Agency—Barnes Chase/Adv.

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editorial . . .

The Girl with the Soldering Iron

WE ARE ALL getting a little tired of the word reliability—but it is probably the most important single word today in the electronics branch of the missile/space industry.

The success of all our missile/space systems depends in large measure on how good a job has been done on the electronics. Here, if anywhere, the traditional twenty-five-cent part can mean crushing defeat for a team that has been working long months toward an important launch. The same is true of the less traditional $250,000 part.

Nowhere is reliability more important than in the field of guidance and control, to which this annual electronics issue is devoted. You will find the word in almost every article. The industry's big problem is to combine the highest reliability of a complex part with the lowest cost.

The firms accomplishing this successfully still will be with us when the guidance and control market passes that $1.5-billion mark. Those failing to meet both standards will find they have been replaced as leaders by hungry, eager and accomplished production teams now close on their heels.

Sheer size is no guarantee of continued success. The missile/space industry is one in which the worth of the electronic design engineer, production engineer, assembly line worker and quality control staff is quickly and openly tested right on the launch pad or in the unforgiving depths of space.

Shoddy work by someone on the transistor production line of General Electric is evident just as fast as shoddy work in a small firm. A few failures can build a bad reputation for a major firm as swiftly as for its smaller competitors, thereby reversing their market standing.

The important part is the one being worked on right now.

The best management team in the world can't make it work. The girl with the soldering iron in her hand can.

We hear frequently that the electronics part of our industry is in a state of flux. So it is, but this is usually said in a manner which indicates we are in a "transition period" which will soon end, meaning just as soon as we get those bums down the street out of business.

We doubt if the day will ever come when missile/space electronics is not in a state of flux. This is a young, vigorous, flexible industry capable of meeting the rapidly-changing requirements of missilery and space exploration.

But if reliability falls off or costs creep up, your firm may next week be begging subcontracts from that bum down the street.

There is another penalty, too, for the firms and individuals participating in this branch of our industry. A considerable amount of money must be poured into research and development. In the guidance field, for example, R&D will take up well over 25% of the money spent this year.

Inertial is coming up; radio command is declining. What do you put your money on? Does optical look better than infrared? Which company should you go to work for? What type of radar looks most promising? No wonder your wife says you look bad lately.

There are other pitfalls to be avoided. One danger in an industry as young as ours is the tendency to follow new trends, perhaps at the risk of both company and national security. For example, there are strong arguments for all-inertial guidance systems. But let's not write off radio command without a good long look at its advantages. Maybe some of that R&D money should be spent exploring them. Let's not jump on the all-inertial bandwagon just because it seems the thing to do at the moment.

IN RETURN FOR these large expenditures of money and brains in missile/space electronics, there are big rewards. The guidance and control market alone is worth nearly $1-billion this year. And that's only a part of the total electronics expenditure in the missile/space field, which is growing faster than the general electronics market.

But perhaps the biggest reward is the chance to participate in the most exciting and nationally important field open today to an individual or firm, young or old: the exploration of space.

You will, however, have to learn to live with the word reliability. No matter how tired of it you get, it's with us to stay and you'll hear it on Mars.

If that girl with the soldering iron doesn't put you out of business before then.

William J. Coughlin

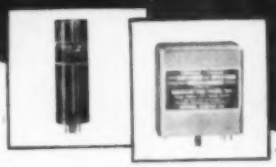
FREQ. STDS.

AND TUNING FORK OSCILLATORS

TYPE 10, ACTUAL SIZE

SIZE, 1-3/8" x 1-3/8" x 3/8"

This frequency standard (360 or 400 cy.) is accurate to ± 25 parts per million at 10° to 35°C. The tuning fork is made from Iso-elastic alloy and is approximately 1 inch long. Fork aging has been greatly minimized. Compensation in the circuit provides a minimum rate change throughout the useful life of the power cell (over a year). External power of 1.4 volts at approximately 6 microamperes can also power the unit. An hermetically sealed model, Type 15, is also available.



TYPE 2007

TYPE 15

For more than 20 years, this company has made frequency standards and fork oscillators within the range of 30 to 30,000 cycles for applications where consistent accuracy and rugged dependability are demanded. A few examples are shown and described here.

Some users integrate these units into instruments of their own manufacture. Others rely on our experience and facilities to develop complete operating assemblies to meet their special needs.

You are invited to submit any problems within the area of our activities for study by our engineering staff.

TYPE K-5A FREQUENCY STANDARD

Size, 3½" x 3" x 1¾"
Weight, 1½ lbs.
Frequency: 400 cycles
Accuracy: .03%, −55° to + 71°C
Input: 28V DC ±10%
Output: 400 cy. approx. sq. wave at 115V into 4000 ohm load (approx. 4W)

TYPE 2007-6 FREQUENCY STANDARD

Transistorized, Silicon type
Size, 1½" dia., x 3½" H., Wt., 7 oz.
Frequencies: 360 to 1000 cy.
Accuracies:
2007-6 ± .02% (−50° to +85°C)
R2007-6 ± .002% (+15° to +35°C)
W2007-6 ± .005% (−65° to +85°C)
Input: 10 to 30V DC at 6 ma.
Output: Multitap, 75 to 100,000 ohms

TYPE 25 PRECISION FORK

Size, ⅜" dia. x 2⅜"
Weight: 2 ounces
Frequencies: 200 to 1000 cy. (specify)
Accuracies:
R-25T and R-25V ± .002% (15° to 35°C)
25T and 25V ± .02% (−65° to 85°C)
For use with tubes or transistors.

TYPE 15 FREQUENCY STANDARD

Similar to Type 10 (illustrated) except with silicon transistor, hermetically sealed and vibration resistant.
Size, 1" x 2" x 2" high
Tolerance, ± .01% from −40°C to + 71°C
Output: .IV at 50,000 ohms source impedance.

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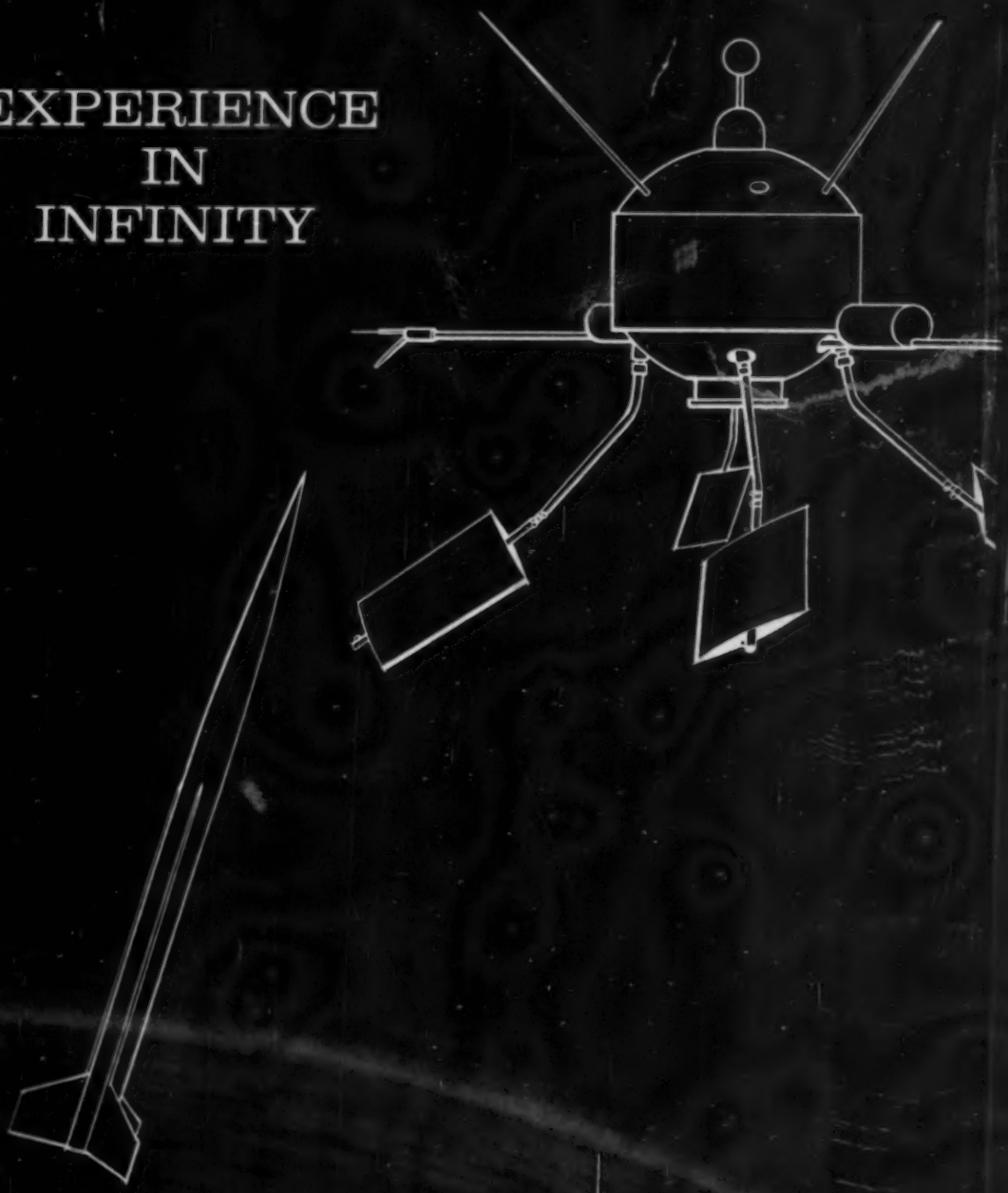

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